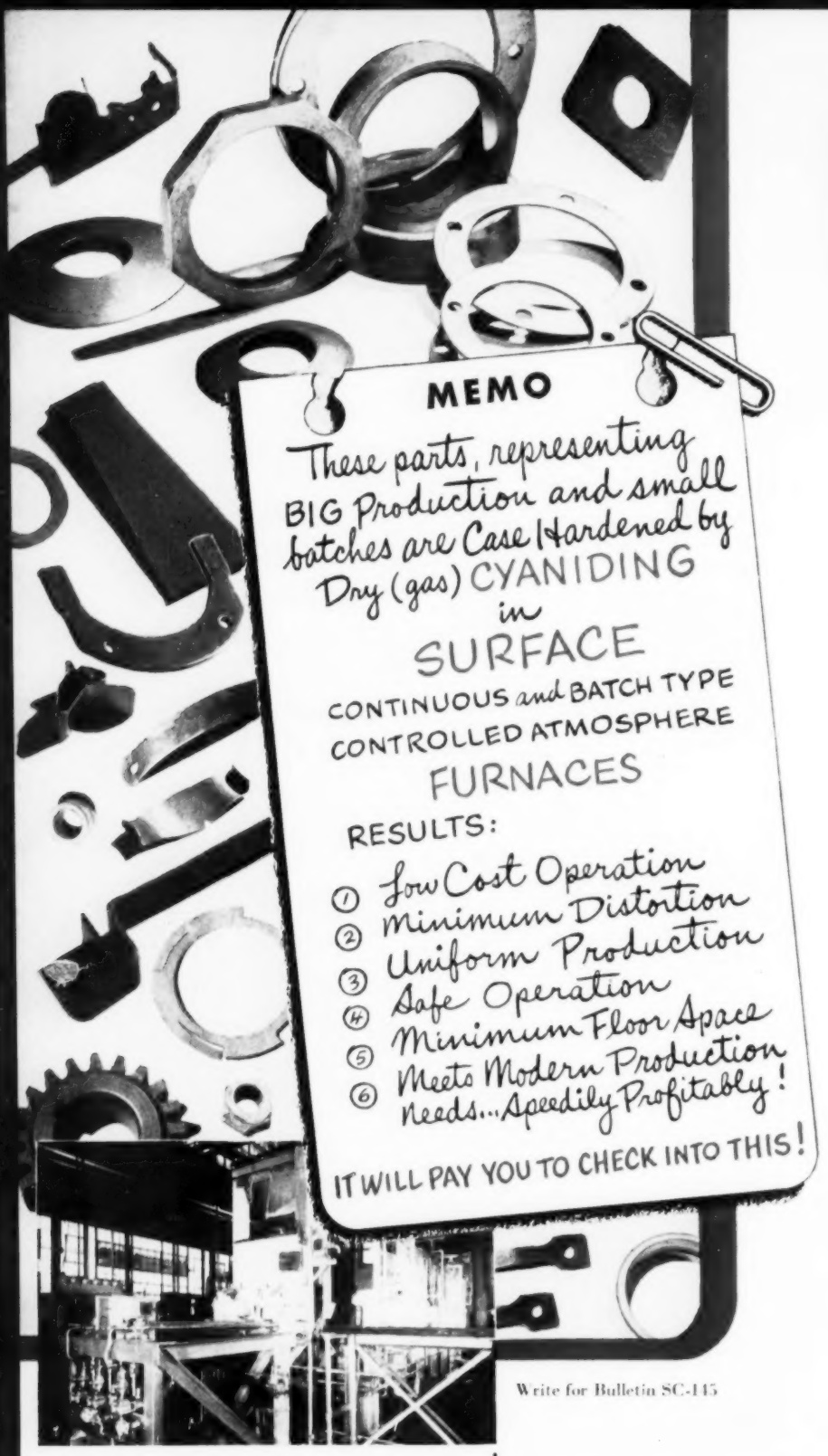
metal progress



Write for Bulletin SC-145

SURFACE COMBUSTION *Corporation*

TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES AND BURNERS

Kathabar HUMIDITY CONDITIONING SYSTEMS

Janitrol AUTOMATIC HEATING EQUIPMENT

PRODUCTION BRIEFS

CONTINUOUS, PUSHER TRAY FURNACE

AUTOMATIC TRANSMISSION PARTS

Production—1600 lb hr. gross.
Temperature—1550 F. followed by quench in oil.
Case Depth—0.040 inches total
Firing System—Radiant tubes, natural gas.

•

BATCH "ALLCASE" HIGH PRODUCTION FURNACE

MISCELLANEOUS PARTS OF LOW CARBON STEEL

Production—1025 lb hr. gross (625 net).
Temperature—1500-1600 F. followed by quench.
Case Depth—As shallow as 0.003-.005 inches.
Firing System—Radiant tubes, natural gas.

•

CONTINUOUS, ROTARY HEARTH FURNACE

AUTOMOTIVE PINIONS AND GEARS

Production—612 lbs hr. net.
Temperature—1550 F. quenched in nitrate bath at 410 F.
Case Depth—0.002-.003 inches.
Firing System—Radiant tubes, natural gas.

•

CONTINUOUS, CAST ALLOY BELT FURNACE

STEERING GEAR PARTS

Production—250-300 lbs hr. net.
Temperature—1575 F. quenched in oil.
Case Depth—0.010-.015 inches total.
Firing System—Radiant tubes, natural gas.

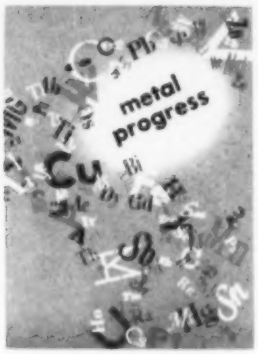
•

CONTINUOUS, PUSHER TRAY FURNACE

MISCELLANEOUS WASHERS

Production—120 lb hr. net.
Temperature—1475 F. cooled in atmosphere.
Case Depth—0.010 inches total, file hard.
Firing System—Radiant tubes, natural gas.

IN THIS ISSUE



Chemical symbols of some of the many elements used by the modern metallurgist were utilized for the cover design by Martha A. Horvath, student at Cleveland School of Art.

Manufacturing Metal Parts

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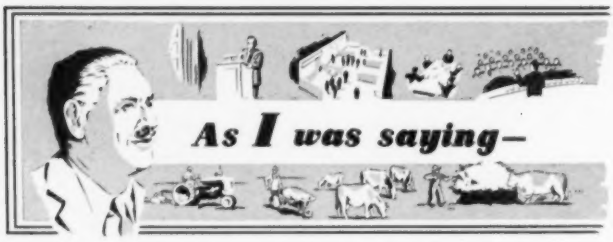
• **See** *Bill's Column on the other side*



WHEN YOU READ this I'll be on the Queen Elizabeth steaming to the London meeting of the British Iron & Steel Institute and the Institute of Metals. I'm sure anticipating this meeting with a great deal of pleasure and I cannot help but feel that it will result in the starting point of the second World Metallurgical Congress. We are constantly hearing reverberations about the first Congress and only yesterday there came to headquarters a report from the Metallurgical Society of India from which I quote: "Also helped select the delegates to the first World Metallurgical Congress held in the United States of America – one of the most important events in the history of metallurgy." Besides the exchange of technical information the most significant and important result was the opportunity for the formation of new and lasting friendships among the scientists of the free world.

The A.S.M. appreciates the honor and confidence the Atomic Energy Commission has exhibited toward your Society. This confidence was first shown about five years ago when Ernest Thum, the distinguished editor of *Metal Progress*, was appointed a member of a committee to review the reports of research and the current investigations and processes at the A.E.C. operations, and recommend which ones, if any, should be declassified and made available to industry. The second show of confidence was the request to the A.S.M. to be the agency to transmit to the profession the "not before revealed" scientific data about the metal zirconium and its alloys. The 21 papers on that subject were presented at the Western Metal Congress last month and will soon be available as a bound volume.

The A.S.M. hopes to continue to merit the confidence of the A.E.C. in these and other ways.

The recent issue of *Metals Review* telling all about the new crop of metallurgical engineers continues to receive high praise from the students, the faculty and industry. The information distributed was really a service to all concerned. Another coming service for *all* engineering students now in school will be off the press before long, just as soon as Walter Morrison, in charge of A.S.M. public relations, can get the material assembled. This information will list the firms offering summer employment to engineering students, the types of jobs, how to apply, preparation of material to be submitted, etc. The jobs offered last year totaled 1860 and it is expected that number will be exceeded this year. These jobs are not just for students in metallurgy but for all engineering students, because, with the metals industry being the largest factor in the American economy (42%), as well as the largest employer of engineering talent of all kinds, it is a fair conclusion that at least one half of the present engineering students will find their life's work in the great metal industry. And why is A.S.M. so interested? Because, A.S.M., as the engineering society of the metals industry, accepts its share of responsibility to bring students and industry together, let them get acquainted, and find out what a happy union can mean for a full and happy life.

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

Thermalloy retorts with bayonet-type plug end on the left. Firebricked ends of carbon steel retorts on the right were sealed over with clay paste before use.

THERMALLOY* outlasts carbon steel retorts . . . 28 to 1

In a plant of a large eastern tool and specialty steel manufacturer, long, pipe-like retorts are used to anneal and heat-treat high-speed carbon and alloy steel bar stock in hood-type furnace equipment. Temperatures range up to 1650°F. during the annealing or heat-treating cycle that may last 30 hours.

Under these conditions, this manufacturer found that wrought carbon steel retorts scaled excessively and also distorted and flattened during operation . . . limiting service life to about 500 cycle hours. For the same operation, centrifugally cast Thermalloy retorts showed no measurable scale loss and maintained uniform wall thickness and shape. When last reported, Thermalloy retorts had been operating over 14,000 cycle hours and were still in perfect condition.

As the wrought carbon steel retorts became distorted, the plugs necessary to seal the open ends would not fit. Firebrick and a clay paste were used to seal the ends against infiltration of furnace gases. This made uniform annealing or heat-treating practically impossible. However, Thermalloy retorts, with plug ends designed by Electro-Alloys, afforded practically gas-tight seals and much greater ease of handling.

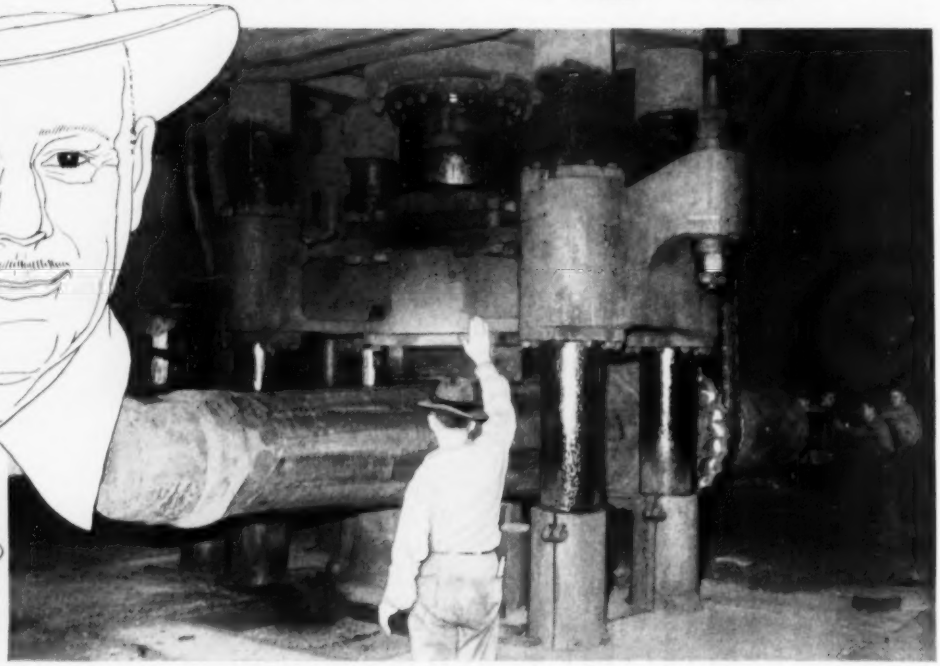
Today, this manufacturer is replacing all of the wrought carbon steel retorts with high heat-resistant Thermalloy retorts. Perhaps the same operating economy may interest you in Thermalloy retorts, furnace parts, trays, racks, pots or muffles. For full information, call in an Electro-Alloys engineer or write Electro-Alloys Division, 4002 Taylor Street, Elyria, Ohio.

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO

FINKL forgings...



... and the MEN who make them

Meet Al, Don, Roy, Tony, Jack, Jim . . . Finkl press smith crews that make quality forgings and die blocks. Here, working with a 78,000 pound ingot of special analysis steel from Finkl's melt shop, these experienced men combine their skill and pride of workmanship to produce forgings and die blocks which prove that the finest product is the least expensive to you in the long run.

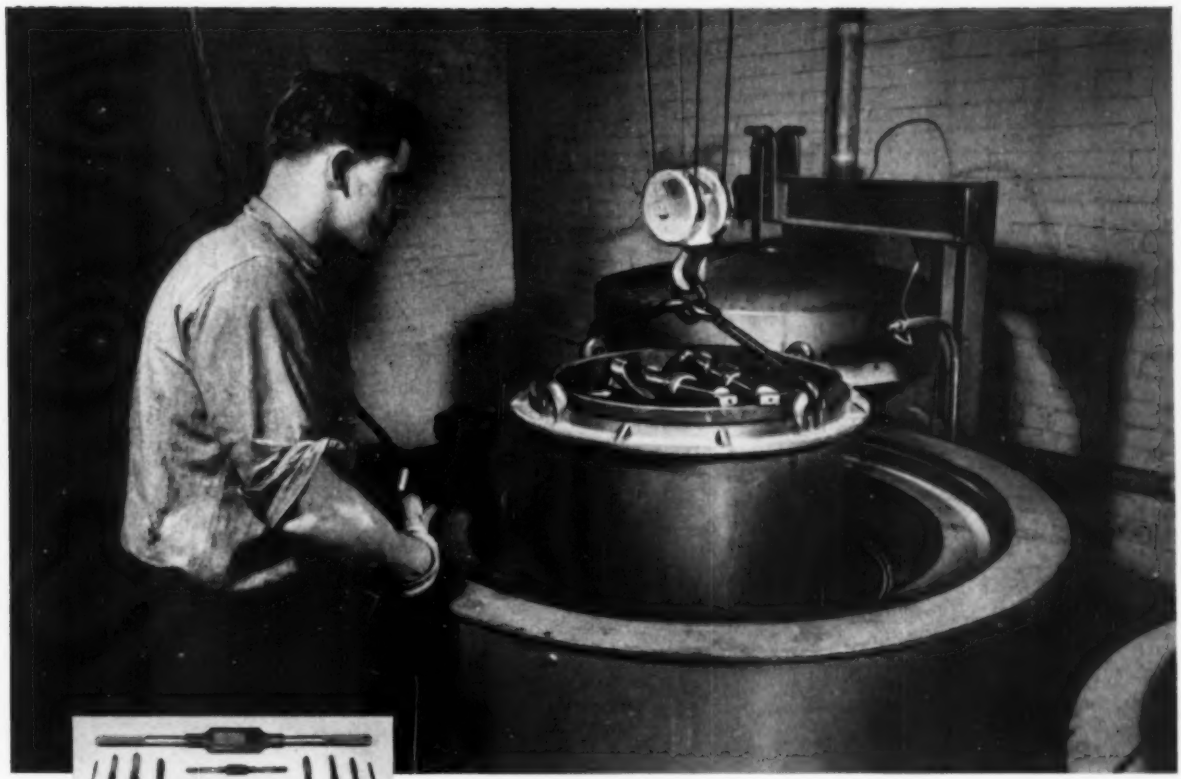
For **74 YEARS**, "Forgings by Finkl" has meant dependability and quality. For **74 YEARS** we have zealously guarded that reputation. And now, with complete control of quality from the analysis of the steel in our own melt shop through to the finished product, we can honestly say that Finkl forgings and die blocks are the finest available at the lowest cost to you.

MANUFACTURERS OF THE LARGEST FORGINGS IN THE MIDDLE WEST

A. Finkl & Sons Co.

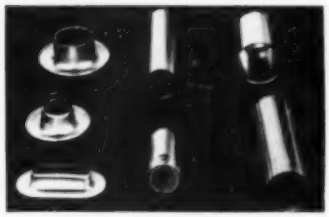
2011 SOUTHPORT AVENUE • CHICAGO 14

ELECTRIC FURNACE STEELS • DIE BLOCKS • FORGINGS



Loads are easily handled in the Steam Homo Furnace.

STEAM ATMOSPHERE HEAT TREATMENT *is becoming standard for many high speed steel cutting tools. It's effective for tools machining average jobs . . . is even better for treating tools handling tough jobs, such as working high-chrome, high-carbon steels.*



COST CUTS OF 53% . . . *in annealing and pickling, effected through steam-atmosphere annealing of these brass stampings.*

For full information about Steam Homo tempering, send for the NEW 12 page catalog, "L&N Steam Homo Method for Heat-Treating". Write our nearest office, or 4927 Stenton Ave., Phila. 44, Pa.

Want Heat-Treating Versatility?

CHECK THESE STEAM HOMO® ADVANTAGES

You get many outstanding heat-treating advantages when you buy the versatile Steam Homo furnace. Here's why:

- Steam Homo gives you scale-free heat-treating of both ferrous and non-ferrous parts at temperatures to 1150 F.

If you're heat-treating ferrous parts:

- The tough oxide film that Steam Homo imparts adds 20-25% more life to high-speed tool steels.
- Steam-treating adds appreciably to the hardness and compressive strength of powdered iron compacts.

Or if you're heat-treating non-ferrous parts:

- Steam atmosphere in many cases eliminates subsequent surface cleaning and pickling operations.

But in both cases you'll get:

- A compactness which makes the Steam Homo equipment ideal for installation directly in production lines.
- A steam atmosphere heat-treating process which is entirely safe and easy to follow.

Standard Steam Homo furnaces are made in a variety of sizes . . . from those with work spaces as small as 11½" x 15" to those as large as 28" x 60". All are supplied as assembled units, ready for installation.

LEEDS NORTHRUP

instruments automatic controls • furnaces

Jrl. Ad. T-620-40

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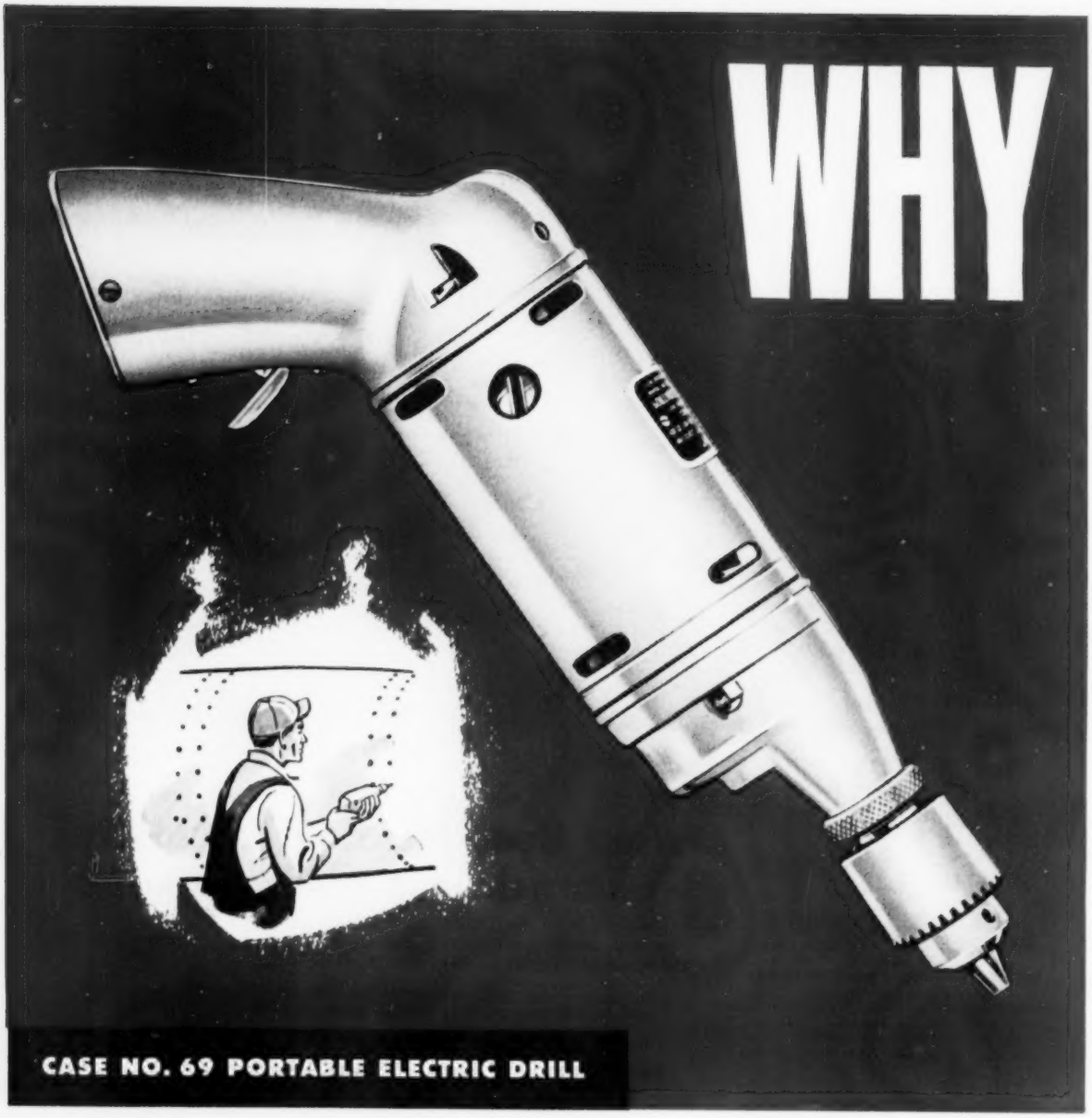
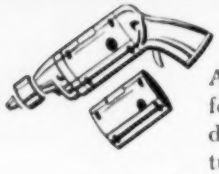




A switch to aluminum tubing for the housing of this electric drill permitted the manufacturer to capitalize on two important features of aluminum . . . its light weight and its naturally attractive finish.

The savings in weight is a direct selling point since lightness is of utmost importance in a hand tool of this kind. Furthermore, the manufacturer effected important savings in shipping costs.

Production and assembly costs were also cut since aluminum is easily fabricated and requires only simple buffing for finishing.

The manufacturer, Portable Electric Tools, Inc., of Chicago, Illinois, discovered also that aluminum is permanently nonrusting, will neither rust nor corrode should it become nicked or worn.

Perhaps this application of aluminum may suggest to you a similar conversion from other materials. Dollar savings in manufacturing and shipping costs, high corrosion resistance, naturally attractive finish plus added sales appeal are yours with aluminum.

LET ALUMINUM SERVE YOU, TOO

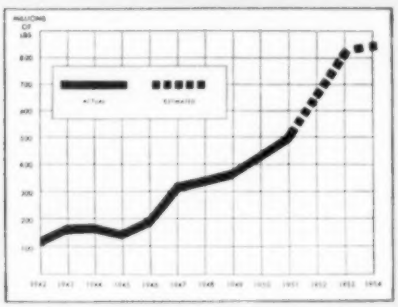
ALUMINUM ?

...because it has an ideal combination of advantages found in no other metal!

More aluminum is being specified in designs today because aluminum improves products and increases sales. Let Reynolds Aluminum Specialists help your designers and engineers get maximum benefits from this modern metal. Remember, only aluminum gives you . . .

- ★ **Lightweight with great strength**
- ★ **Consistently low cost**
  no more now than before World War II
- ★ **Natural resistance to rust and corrosion**
- ☆ **Attractive appearance**
- ★ **Ease of fabrication by modern methods**

STILL MORE ALUMINUM COMING



The expanding primary aluminum production of Reynolds Metals Company . . . a historic chapter in the company's 33 years of continuing growth. And primary supplies of aluminum ore will be ample for generations.

To the man in charge of production

Acquaint yourself with accepted techniques for fabricating aluminum. Write on your letterhead for aluminum fabrication books listed at right. On special problems consult with Reynolds staff of aluminum specialists. Reynolds Metals Company, 2519 South Third Street, Louisville 1, Kentucky.

Yours For The Asking . . .
REYNOLDS TECHNICAL BOOKS

(please request on business letterhead)

- Aluminum Data Book
  (Aluminum Alloys and Mill Products)
- Aluminum Structural Design
- Aluminum Powders and Pastes
- Designing with Aluminum Extrusions
- Fastening Methods for Aluminum
- Finishes for Aluminum
- Forming Aluminum
- Heat Treating Aluminum Alloys
- Machining Aluminum Alloys
- Welding Aluminum
- Metals Weight Slide Rule

Complete index of all technical literature and films on aluminum design and fabrication also available.

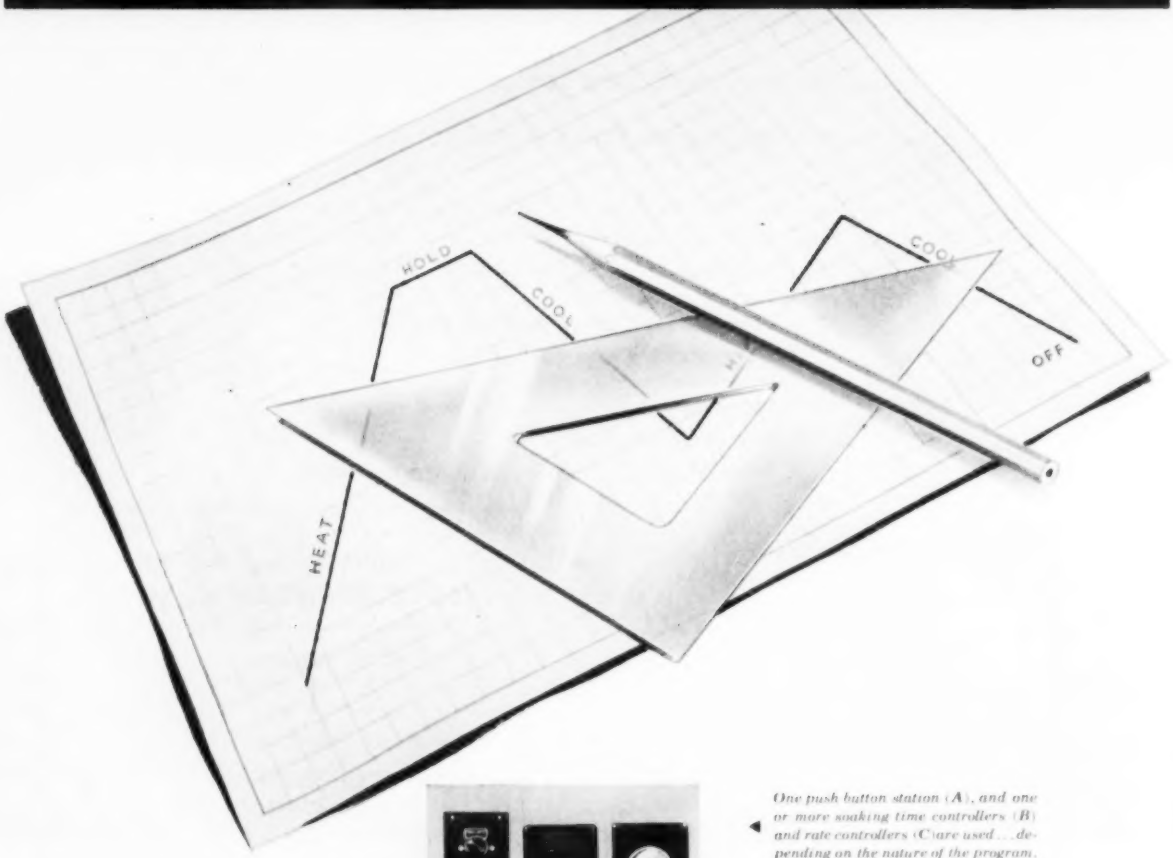
Be sure to see "Mister Peepers" every Sunday night, 7:30 EST, NBC-TV; hear "Fibber McGee and Molly" every Tuesday night, 9:30 EST & PST, NBC

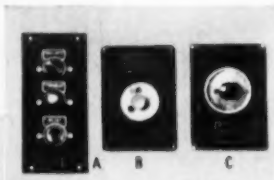
REYNOLDS ALUMINUM

MODERN DESIGN HAS ALUMINUM IN MIND

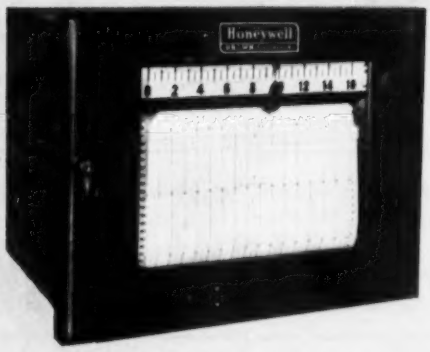
Plan Time *vs*

any way you like . . . with NEW





One push button station (A), and one or more soaking time controllers (B) and rate controllers (C) are used . . . depending on the nature of the program.



BROWN PROGRAM CONTROLLER WITH MOTOR DRIVEN INDEX

. . . the peak in flexibility, providing an infinite variety of programs. Heating or cooling rates are calibrated in degrees hour, soaking time in hours or minutes . . . both are easily set. Three front-of-instrument temperature settings are available at which heating rate can change or soaking begin. Automatic change from heating to artificial cooling can be provided. Multi-zone control is also available.

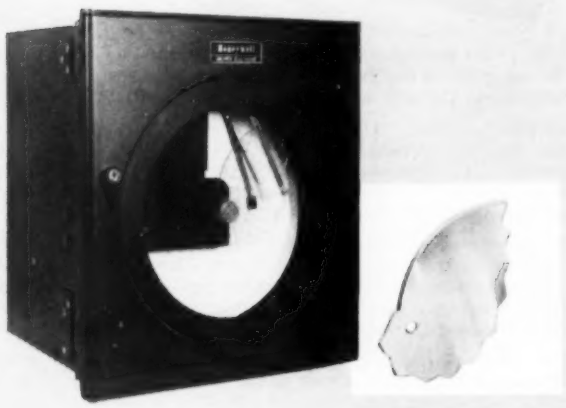
Temperature

ElectroniK Program Control

Now, ElectroniK Program Controllers offer you a free hand in securing automatic regulation of time-temperature cycles. The way these controllers conduct furnaces through complete heating, cooling and soaking periods . . . signalling operators when critical points are reached . . . shutting off equipment at the end of the cycle . . . makes them exceed human abilities.

ElectroniK Program Controllers are designed for complete systems. Available with all varieties of electric and pneumatic control forms (including time or position-proportioning control). For a discussion of how this new, advanced control can improve your production, call in our local engineering representative . . . he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division, 4503* Wayne Ave., Philadelphia 44, Pa.



BROWN CAM-OPERATED PROGRAM CONTROLLER

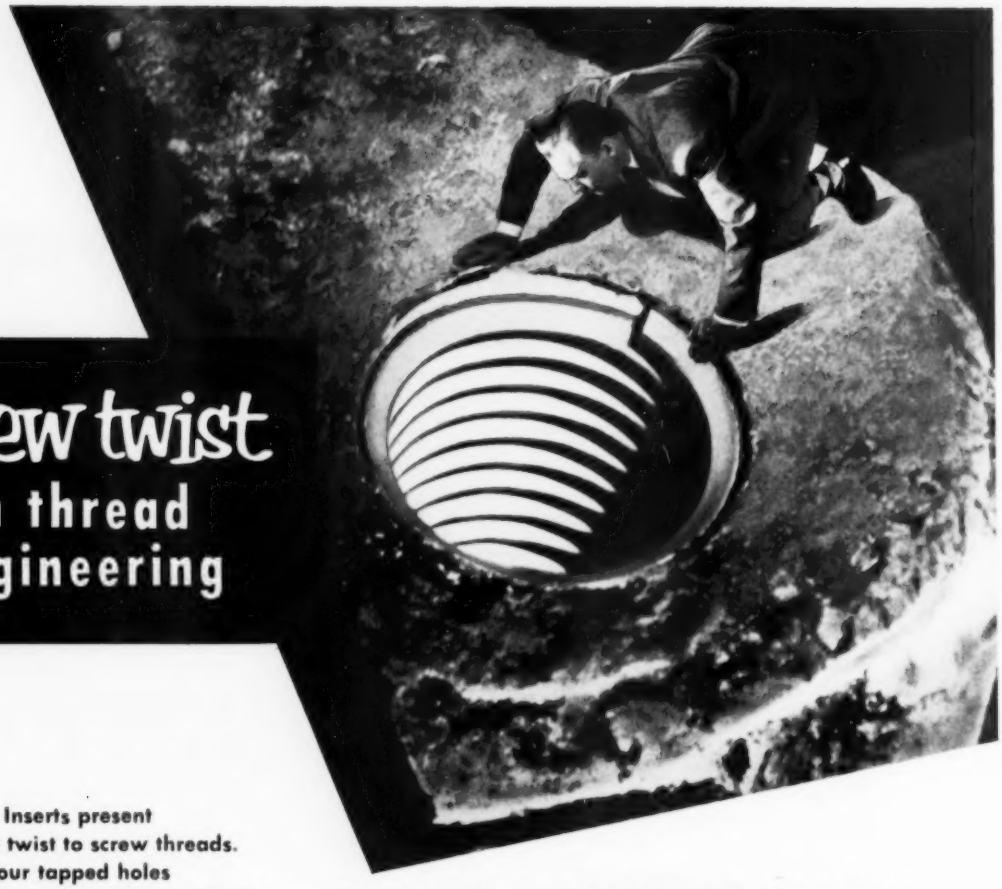
. . . for frequently repeated cycles. Cam is easily cut to desired time-pattern on calibrated disc of clear plastic. Nonlinear rise or fall is readily produced. Any number of heating, cooling and holding periods can be incorporated. Entire program is readily apparent, and can be duplicated at any time. Program change requires only the replacement of the cam.

Plastic cams are easily cut to any desired pattern.

● **REFERENCE DATA:** Write for Bulletin 1501, "*ElectroniK* strip chart program controllers". . and Bulletin 1502, "*ElectroniK* circular chart program controllers".

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

a new twist in thread engineering



Heli-Coil Inserts present a new twist to screw threads. They armor your tapped holes with precision-formed stainless steel wire, and put an end to stripping and corrosion.*

This alone will be a decided advantage for your products in the competitive market. But there are still further basic design improvements and savings possible with ***Heli-Coil*** Inserts.

Smaller . . . fewer . . . or shorter cap screws can now provide the necessary holding power with ***Heli-Coil*** Inserts . . . even with short thread engagements. Cap screws can be repeatedly removed and replaced without damage to the threaded member when tapped threads are protected by ***Heli-Coil*** Inserts.

Make your designs cleaner, with lighter bosses and smaller flanges – by the use of ***Heli-Coil*** Inserts. Eliminate heavy studs and bolt-and-nut assemblies by using cap screws and ***Heli-Coil*** Inserts. In addition, your product is permanently protected against thread corrosion and seizure.

The value of ***Heli-Coil*** thread engineering to you is quickly verified. Take a minute now to get the latest information. It costs you nothing...mail coupon today!

Conforms to all industrial and military specifications.

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How the Fable of

"The Birds, The Beasts & The Bat"

has a parallel in Cutting Fluids

...thanks to Aesop for this Fable

The Birds were engaged in a fierce battle with the Beasts. The Bat figured he could pass as either a Bird or a Beast and he wanted to be on the winning side. As the battle see-sawed he flitted back and forth. The Birds finally won but the Bat got back to their side too late and was chased away to a cave, where he has lived ever since, ashamed to come out except at night.

The Parallel...

Like the Bat in the fable, some cutting fluids appear to be both Bird and Beast, but may be neither. If you are going to tap a tough, difficult to machine metal you need a heavy duty cutting oil with high *anti-weld* and good *lubricity* characteristics. On a less exacting light milling job a conventional water-mix fluid with good temperature regulating properties is usually the answer.

The point the fable emphasizes is that a cutting fluid can't be on both sides of the fence. You don't need a different fluid for every job but you need one that's *right* for the job. Stuart products and Stuart experience will give you the best possible results in terms of finish, tool life and production. Ask to have this demonstrated to you by a Stuar Representative.

More Than a "Coolant" is Needed

D.A. Stuart Oil co.
EST. 1865 LIMITED

TIME-TESTED CUTTING FLUIDS AND LUBRICANTS

2743 S. Troy St., Chicago 23, Ill.

SEND FOR BOOKLET *entitled More Than a "Coolant" is Needed*

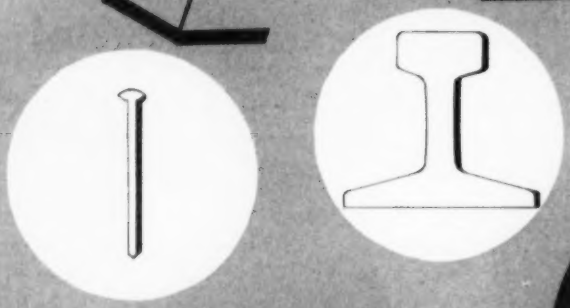
CLIP TO YOUR COMPANY LETTERHEAD AND MAIL

to D. A. Stuart Oil Co., Ltd., 2743 S. Troy St., Chicago 23, Ill.

Your Name .....

Title .....

FROM SURGICAL NAILS TO STEEL RAILS



you can test practically anything with a

RIEHLE UNIVERSAL TESTING MACHINE

Compression test in progress on Riehle 60,000 lb. Hydraulic Universal. Photo courtesy of Bundy Tubing Company, Detroit.

When you install a Riehle Pendomatic Universal Testing Machine, it's just like having 5 testing machines at your disposal. That's because every Riehle Pendomatic Universal has 5 scale ranges as standard equipment. All you do is turn the selector knob to the proper range, then conduct the test. No accessories are needed. Guaranteed accuracy is within ½ of 1%.

On the same Riehle machine, you can test specimens with relatively low rupture points, or high yield point specimens. Only Riehle builds testing machines with 5 scale ranges, and only with a Riehle Pendomatic do you get complete coverage of the machine's full capacity.

HYDRAULIC OR SCREW POWER?

What type of loading unit is best for testing machines? Our engineers will be glad to make recommendations for your specific requirements. We build both hydraulic and screw power machines in all sizes up through 400,000 lbs. capacity. Ask your Riehle representative or write our factory for illustrated catalogs.

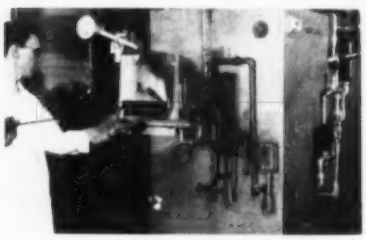
RIEHLE TESTING MACHINES

Division of AMERICAN MACHINE AND METALS, INC.
EAST MOLINE, ILLINOIS

"ONE TEST IS WORTH A THOUSAND EXPERT OPINIONS"

3100° F. Heat Treating Furnace

Temperatures up to 3100° F. can be obtained in a new heat treating furnace available from Westinghouse Electric Corp. A water-jacketed chamber, an integral part of the furnace, permits work to be cooled as well as heated in a protective atmosphere. The furnace is designed for use of either hydrogen or dissociated ammonia. Four manually operated, counterbalanced doors on the furnace separate its charging, heating and cooling chambers. Intended for batch-type heating, the work is handled on trays and manipulated by push and pull rods. Ample cooling surface is provided to assure cooling of the charge below the oxidation point before it is discharged. Heating elements are formed from heavy molyb-



denum alloy rod into sinuous loops and supported on alundum refractories. The furnace hearth is made of molybdenum alloy to prevent warpage and provide a smooth, hard surface over which the trays are easily moved. Protective atmosphere consumption is between 150 and 200 cu.ft. per hr.

For further information circle No. 953 on literature request card on p. 32B

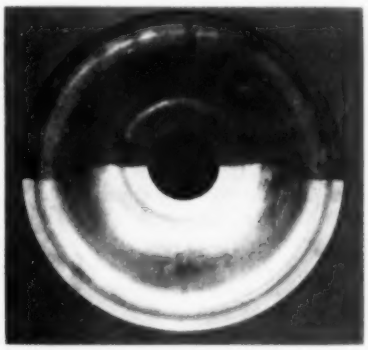
Black Finish

Special Chemicals Corp. announces new, improved features in their Dipblack process. Among the characteristics of the new process is its versatility of application to all types of ferrous metals which makes it useful on assembled units consisting of different types of iron and steel. A specially prepared replenishing salt maintains the solution in proper balance, assuring a uniform black finish. An inhibition agent protects workers and keeps the solution from running down the outside of the tank.

For further information circle No. 954 on literature request card on p. 32B

Acid Derusting and Descaling

Enthone, Inc., has announced Descaler 2A for rapid removal of oxide and scale from steel. The acidic product is a dry powder, containing surfactants to dislodge oil films, promote faster pickling and give a white clean surface after descaling or derusting.



It is suitable for tumble or barrel derusting or descaling and is also used for removal of rust or scale in vats or tanks, for primary pickling or for plating cycles. The accompanying illustration shows heavily rusted and scaled steel, the lower portion of which has been pickled with Descaler 2A.

For further information circle No. 955 on literature request card on p. 32B

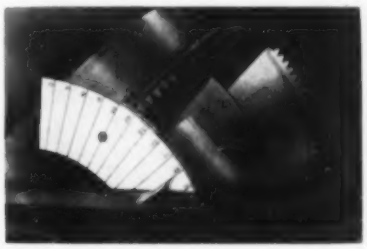
Cut-Off Wheel

The Allison Co. wheel for cutting refractory brick has an entirely new combination blotter and arbor hole bushing to provide simple, trouble-free mounting, with extra protection to both the wheel and the spindle.

For further information circle No. 956 on literature request card on p. 32B

Welding Positioner Protractor

Aronson Machine Co. has announced a protractor for attachment to the



tilt trunnion on the control side of a welding positioner where it is readily seen by the operator when tilting the table. Precise tilt angles are easily obtained every time the table is tilted.

For further information circle No. 957 on literature request card on p. 32B

Screw Steel

A new, free-machining openhearth steel for screws, nuts, studs, bolts, and other small machined parts, is now being produced by Jones & Laughlin. The new steel is furnished as cold finished bars. Tests and production trials have shown that this steel, designated J&L 1200 series (SAE 1100), gives greater uniformity, superior machinability, and a higher quality finish than conventional screw stock.

For further information circle No. 958 on literature request card on p. 32B

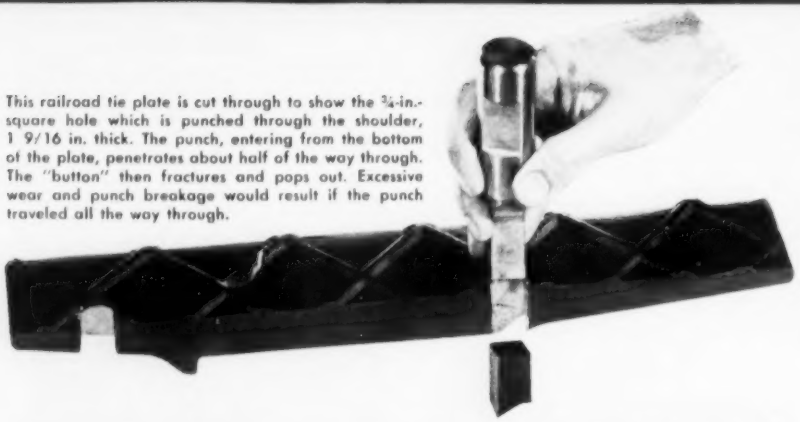
Decorative Plating Process

Promat Div., Poor & Co., has developed two decorative plating processes for use on parts commonly having a copper-nickel-chromium finish, designated as Probrite CR-723, a buffing grade deposit for parts that can be color buffed after plating. Finishes can be deposited over steel or copper. They can be readily chromium plated.

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributors: Bethlehem Steel Export Corporation



This railroad tie plate is cut through to show the ¾-in.-square hole which is punched through the shoulder, 1 9/16 in. thick. The punch, entering from the bottom of the plate, penetrates about half of the way through. The "button" then fractures and pops out. Excessive wear and punch breakage would result if the punch traveled all the way through.

Omega Adds 5 Lives To Rugged Punches

When a punch can average only 54 holes before failure, you would figure that the job is a tough one. And you would be right. Punching ¾-in.-square holes through 1 9/16-in. of tough steel in railroad tie plates is no job for an ordinary tool steel.

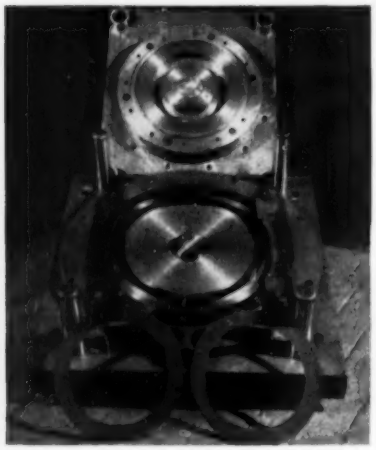
One of our metallurgical contact men studied this severe punching operation and recommended the use of our Omega tool steel. He pointed out to the shop men that it takes a shock-resisting tool steel — and a good one — to punch a hole that's smaller in diameter than the thickness of the steel. And in this case the steel plate is twice as thick as the width of the ¾-in.-square hole.

The first few punches made from Omega averaged well over 100 holes. So they made up 102 Omega punches and used them on a production basis. These produced 2 holes each in 18,160 plates — an average of 356 holes per punch, and more than 5 times the service life of the steel previously used.

This is another example of the way Omega can master heavy-shock applications. It's been doing a fine job for years on such tools as: pneumatic chisels, pawls, punches, knockout pins, swaging dies, shear blades, clutch and machine parts.

Omega is tops for cold-shock jobs. Your Bethlehem tool-steel distributor carries Omega in his stock for fast delivery. Its typical analysis:

C	Mn	Si	Mo	Va
.60	.70	1.85	.45	.20



⇐ Blanking High-Carbon Sheets

The excellent shock-resisting properties of our 67 Chisel make it a good choice for the blanking of clutch-plate discs from .09-in., high-carbon sheet steel. Operating in a 350-ton press, this die produces about 30,000 pieces before any redressing is needed. The die is hardened to Rockwell C-53.

Despite its reputation for shock applications, 67 Chisel has plenty of wear-resistance for blanking tools, punches, swaging dies, hot-work tools, shear blades and master hobs. It's easy to carburize 67 Chisel whenever extra wear-resistance is needed . . . without sacrificing its tough core.

Stocked by Bethlehem tool steel distributors, 67 Chisel is easy to machine and heat-treat. Its typical analysis:

C	Si	Cr	W	V
.50	.75	1.25	2.50	.20

Dies That Hold Their Size

Being machined is a piece of Lehigh H for a progressive die that will blank, form and draw a precision part from 3/16-in. steel strip. When you machine a piece of our Lehigh H tool steel you can be sure that it's going to hold those accurate dimensions during heat-treatment. Distortion and warpage are held to the very minimum.

This high-carbon, high-chromium grade is also first choice for long wear and high compressive loads. And because Lehigh H is air-hardening there's little chance of quenching-cracks, even when dies have intricate designs.

Lehigh H is stocked in many sizes by Bethlehem tool steel distributors everywhere. Its typical analysis:

C	Cr	Mo	V
1.55	11.50	.80	.40

BETHLEHEM TOOL STEEL ENGINEER SAYS:

It's better to grind round tool steel bars than to cold-draw them.

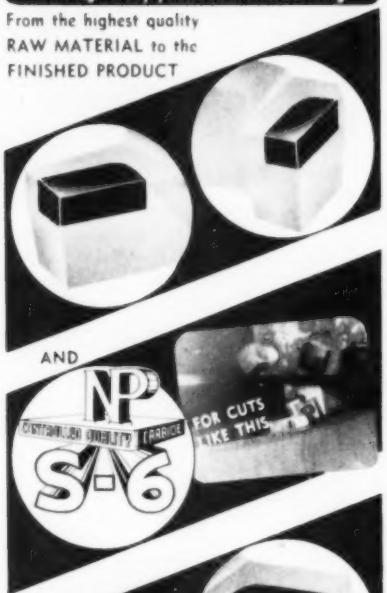
Because tool steel is inherently hard and brittle, it's ordinarily best not to specify that it be furnished in the cold-drawn condition. When very close size-tolerances are required, round bars are sometimes cold-drawn.

However, cold-drawing does *not* remove minor surface defects or decarburization. The surface of a cold-drawn bar must be machined off — just as with a hot-rolled bar — before tools are heat-treated. Otherwise, tools may crack in heat-treatment and will have a soft "skin."

It's better to finish round bars by centerless grinding, because the grinding does remove minor surface defects and decarburization. Tools can be made from ground bars without first machining off the surface.

Tool steel in sections other than round must usually be furnished cold-drawn if tolerances have to be close, because such sections as flats and squares cannot be surface-ground economically.

NP
CONTROLLED QUALITY CARBIDE
NEWCOMER CARBIDES
MEANS
CONTROLLED
QUALITY
through every phase of manufacturing
From the highest quality
RAW MATERIAL to the
FINISHED PRODUCT



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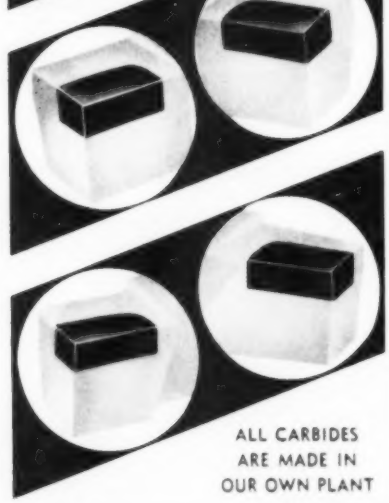


ALL CARBIDES
ARE MADE IN
OUR OWN PLANT

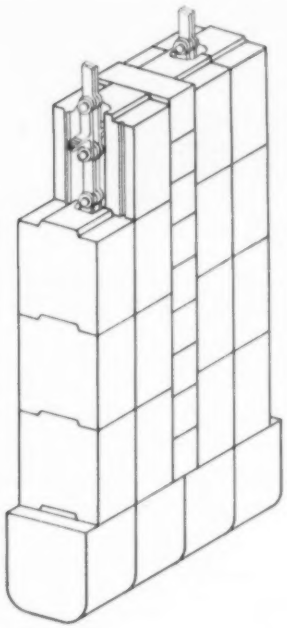
NEWCOMER PRODUCTS, INC.
General Sales Office
PITTSBURGH 21, PA.
Plant at LATROBE, PA.

No nickel is employed. A new sealer for use over the chromium plating prolongs life of the finish.

For further information circle No. 959 on literature request card on p. 32B

Furnace Curtain Wall

The Reintjes link-supported refractory curtain wall is designed so that the weight of each unit of refractories is transferred to the metal links. This eliminates refractories in tension,



thereby permitting the use of lightweight refractories, silica refractories, acid brick tiles, or high-alumina refractories, as required for the particular application. The construction is especially applicable to forging and heat treating furnaces.

For further information circle No. 960 on literature request card on p. 32B

Electrode Plater

Designed to platinum plate electrodes for chemical analysis, this unit has considerable use for plating other metals and as a source of direct current. It is manufactured by Laboratory Equipment Corp. Plugged into a 115-v., 60-cycle source, it is a full-wave rectifier, delivering up to 6-v. d.c. and up to 900 milliamperes. A current reversing switch is useful for plating first on one electrode and then on the other.

For further information circle No. 961 on literature request card on p. 32B

Reversing Control

A new combined temperature recorder and temperature-difference

Get the
"HURRY-UP"
Vacuum Pump

"Time is of the essence" in vacuum processing. That's why more vacuum processes depend on high-efficiency Kinney Vacuum Pumps . . . the fastest mechanical, oil-sealed vacuum pumps on the market. There are nine Kinney Single Stage Pumps and four Compound Pumps . . . all built for speed . . . all designed to give maximum vacuum per dollar of power and per minute of processing time. Kinney Manufacturing Co., Boston 30, Mass. Manufacturers of Vacuum and Liquid Pumps. Representatives throughout the United States and foreign countries.

SEND COUPON FOR DETAILS!

Kinney
SUBSIDIARY OF THE NEW YORK AIR BRAKE CO.

Kinney Manufacturing Co.
3584 Washington Street
Boston 30, Mass.

Please send Bulletin V-51B describing the complete line of Kinney Vacuum Pumps.

Name
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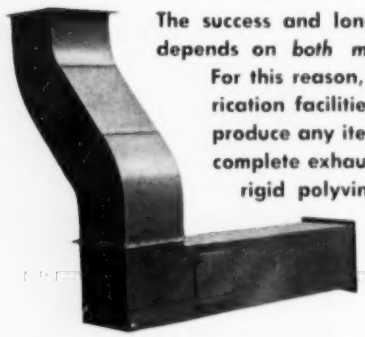
Economical protection that is built...NOT APPLIED

AMPCOFLEX® is an unplasticized, rigid polyvinyl chloride. It is corrosion-proof all the way through . . . and self-supporting as well. It has no coating to wear with time . . . nor edges or undersurfaces that ever become exposed and corrode. AMPCOFLEX Fabrications provide you with the long-term, economical solution to many industrial corrosion problems.

While only one-half the weight of aluminum, AMPCOFLEX has a tensile strength of 9000 psi at 75° F. It is inert to most acids, salts, alkalies and standard pickling and plating solutions.

One of the more important uses of AMPCOFLEX is for fume exhaust systems. Here, additional properties of impermeability, high dielectric strength and low fluid friction factor are definite advantages.

AMPCOFLEX...*plus ATLAS specialized experience and fabrication facilities*



The success and long life of a corrosion-proof structure depends on *both materials and construction techniques.* For this reason, ATLAS has developed complete fabrication facilities for AMPCOFLEX. ATLAS shops will produce any item from small trays to large tanks and complete exhaust systems fabricated of unplasticized, rigid polyvinyl AMPCOFLEX. In addition, ATLAS will furnish necessary pipe, pipe fittings and accessories.

For complete data, write for Bulletin 9-1.
ATLAS MINERAL PRODUCTS CO.
MERTZTOWN, PENNA. • Houston 1, Texas

... self-supporting, corrosion-proof structures

ATLAS Ampcoflex
FABRICATIONS

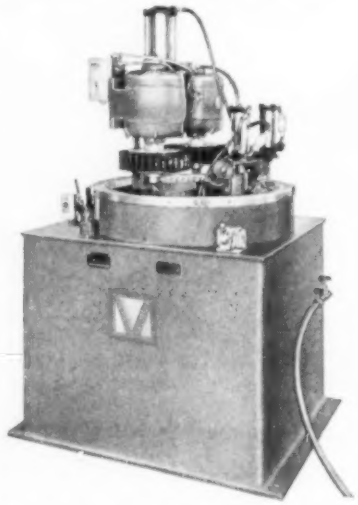
controller for fast, accurate reversal of regenerative furnaces is now being offered by Leeds & Northrup Co. The controller provides — in one instrument instead of the conventional two — continuous recording of checker temperature, simultaneous measuring of temperature-difference between regenerators, and either automatic fur-

nace reversal or warning for manual reversal when preset difference is reached. The controller draws a two-point continuous line record of the temperatures of checkers at opposite ends of the furnace. It plots a record of high and low temperatures, with the width of the recorded band between them showing temperature-difference.

For further information circle No. 962 on literature request card on p. 32B

Deburring Machine

A new turntable-type machine for rapid deburring of compressor stator rings, half rings or other ring sections has been developed by Grinding



& Polishing Machinery Corp. Provision is made for holding ring sections to very accurate diameter during the

tool steel is our special pride!

Just as mother was known for a special dish, so Crucible stands for the finest in tool steel. For a half-century we have enjoyed this reputation. Naturally, we are proud of it.

We are keeping our research and development in step with industry's everchanging needs for tool steel. We are offering you the benefits of our metallurgical service to solve unusual problems. And we are maintaining full stocks in conveniently-located warehouses so you can get prompt delivery of tool steel.

SEND TODAY for the unique Crucible Tool Steel Selector—a twist of the dial gives the tool steel for your application.

Rex® High Speed Steels
Peerless Hot Work Steels
Halcomb 218
Chro-Mow®
Sanderson Carbon Tool Steels
Ketos®
Airkool Die Steel
Airdi® 150
Nu-Die V Die Casting Steel
CSM 2 Mold Steel
La Belle® Silicon #2
Atha Pneu

SPECIFY YOUR TOOL STEELS BY THESE BRAND NAMES

Crucible Steel Company of America

Dept. MP, Chrysler Building, New York 17, N. Y.

Name_____

Company_____ Title_____

Address_____ City_____ State_____

9" diameter, 3-colors

CRUCIBLE first name in special purpose steels

53 years of Fine steelmaking

TOOL STEELS

CRUCIBLE STEEL COMPANY OF AMERICA • TOOL STEEL SALES • SYRACUSE, N. Y.

PACEMAKER 150-T OIL WAS USED
to replace previous oil that was causing deterioration of gaskets and packing of the injection molding machine shown here.

PACEMAKER 150-T OIL SAVES MANUFACTURER UP TO $600.00 PER MONTH

The injection molding machine (shown above) of Plasticks Inc. of Chicago was operating under 1000 p.s.i. at a water-controlled oil heat of 100° F to 120° F, 24 hours per day, 7 days a week.

THEN CAME TROUBLE! The hydraulic oil they were using was seriously damaging gaskets and packing. So, they called in their Cities Service Representative . . . and he recommended Cities Service Pacemaker 150-T Oil.

THE RESULTS WERE PHENOMENAL! With Pacemaker 150-T, the machine was able to run far longer on an oil change than ever before! Machine filters were cleaner with each change. Gumming and deterioration were eliminated! . . . AND DOWNTIME WAS CUT 20% to 25% AT THE AMAZING SAVINGS OF $450.00 to $600.00 PER MONTH!

You too can realize big dollar savings and increase production by relying on the full line of Cities Service Industrial Lubricants. Call your nearest Cities Service Representative, or write Cities Service Oil Company, Dept. D14, Sixty Wall Tower, New York City 5, New York.

CITIES SERVICE
QUALITY PETROLEUM PRODUCTS

JESSOP Announces the First Complete Line of Tempered-and-Ground Flat Steels in America!

In keeping with Jessop's drive for unqualified leadership in the production of specialty steels, is this new manufacturing development at the Washington mill. Through a continuous process, carefully-controlled, ground-and-polished carbon, alloy, and stainless flat steels in widths up to 24 inches and in all applicable cut lengths, are available in large quantities. For example, the automatic furnace equipment alone is capable of processing a normal 7,000,000 pounds per year. Such steels in quantity were formerly obtainable only in Europe, on an average delivery schedule of at least 18 months. Now, you can get them from Jessop in a few weeks. This new availability should be of high interest to the makers of band saws, paper mill machinery, food packing equipment, textile machinery, and all others that require tempered steel with fine surface finish, flatness, straightness, accuracy of gauge, and exact composition. When inquiring, mention TRU-GROUND, which is the trade name of this new steel . . . this prime example of Jessop enterprise.

JESSOP

STEEL COMPANY · WASHINGTON, PA.

MORE FACTS ON GETTING **A BETTER START FOR YOUR FINISH**

A SUPERIOR ALL-PURPOSE NON-ETCHING CLEANER **for ALUMINUM**

HERE is a true advancement in aluminum cleaning! A new, versatile, dependable product that does a far better job—usually in less time and at lower cost!

Pennsalt Cleaner A-27 is a granular material—dry, free-flowing, and dust-free. Its special formulation provides maximum detergency and free rinsing—yet it will not attack or stain the aluminum.

A-27 has an outstanding ability to *thoroughly* remove tough soils, including red and black marking inks, finger marks, cutting oils, and other shop grime. It rinses quickly and completely, *even if it is allowed to dry on the work, and it will not streak or stain.*

Pennsalt Cleaner A-27 is highly recommended for cleaning aluminum sheet stock prior to anodizing, chromatizing, phosphatizing, or other surface treatment. *And note this:* even though A-27 gives vastly superior results, it costs the same or less than other makes of aluminum cleaners!

This great new product is part of a complete aluminum "package" Pennsalt now offers to fabricators. To help you use these materials with maximum efficiency, Pennsalt's Metal Processing Service fieldmen will be happy to apply their experience to your operation.

For information about Cleaner A-27, or any of the products in the Pennsalt aluminum "package", write to: Metal Processing Service, Pennsylvania Salt Manufacturing Company, *East:* 279 Widener Building, Philadelphia 7, Pa. *West:* Woolsey Building, 2168 Shattuck Ave., Berkeley 4, Calif.

Pennsalt Chemicals

The Pennsalt Aluminum "Package"

Pennsalt Cleaner AE-16. A new, non-scaling, non-sludging etchant. Produces exceptionally uniform etch. Rinses free. Can be cleaned from tank with stream of water.

Pennsalt Aldox°. A new, powdered, acid-type desmutter and deoxidizer. Replaces nitric acid, does away with carboys and fumes.

Pennsalt Cleaner # 85. An alkaline cleaner and deoxidizing agent recommended when aluminum is coated with heavy layer of oil.

Pennsalt Cleaner MC-1R. An unusually economical general purpose cleaner and deoxidizer.

Pennsalt Cleaner EC-51R. A non-staining, organic-type emulsion cleaner.

Pennsalt Cleaner EC-54R. An emulsion cleaner which will not boil off, evaporate, or flash at use temperatures.

°Trademark of PSM Co.

deburring operation by interchangeable holding fixtures for different diameters of workpieces. Modifications of this design can be readily adapted for deburring other circular workpieces. Previous hand methods of deburring 32-in. diameter aluminum half rings required an 8-hr. day for a set of 24 half rings. This machine does the job in 12 min.

For further information circle No. 963 on literature request card on p. 32B

Portable Instrument Serves as Spare

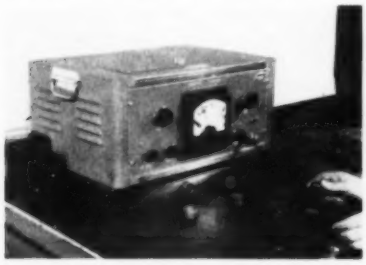
A portable Foxboro potentiometer indicator spots impending thermocouple failure, tests the operation of other pyrometer instruments, and

checks such equipment as heating units and test furnaces which may not warrant continuous measurement. Additionally, the portable instrument is valuable as a stand-by, replacing any installed potentiometer temporarily out of service. Designed for rugged use, the instrument is enclosed in a metal case and weighs only 14 lb.

For further information circle No. 964 on literature request card on p. 32B

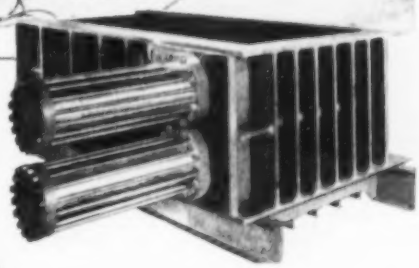
Metals Comparator

Better quality control and reduced testing costs have resulted from the



use of an electronic metals comparator, a General Electric product designed to detect and indicate variations in the hardness of metals by measuring differences in magnetic characteristics. In one application, universal transmission yoke bearings, after heat

D & J PRESS CO. LINES THEIR BALING PRESSES WITH SPEED TREAT STEEL PLATE TO STAND THE GAFF!



D & J Press Co., Inc., Buffalo, N. Y., builds scrap baling presses large enough to take an automobile and compress it into a bale 2' x 2' x 5', weighing about 1-ton. The charging box is 6' wide, 5' deep, 14' long. Compression, from one end and one side, is furnished by two 14", 2,000 lb. cylinders and two 17", 2,000 lb. cylinders. Construction is welded heavy boiler plate. Charging box and platens are lined with ¾" SPEED TREAT (X1545) open hearth, medium carbon steel plate — selected because it is so easy to machine (in this case, drilling holes), and because it ably resists abrasion and impact. In this application the SPEED TREAT plate has a tendency to work-harden and resists gouging.

SPEED TREAT Steel, one of the Speed Steels, has remarkable physical properties — speeds machining, increases tool life, readily polishes to a high lustre, suited to flame or induction hardening and other treatment — widely used for machine parts, hardened gears and sprockets, rubber molds, short run blanking dies, etc. Consult your nearest distributor.

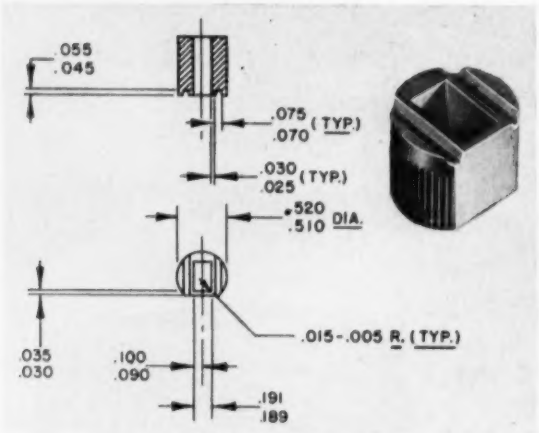
DISTRIBUTED BY

Brown-Wales Co., Cambridge-Hartford-Auburn. - Bridgeport Steel Co., Milford, Conn. Beals, McCarthy & Rogers, Buffalo, N. Y. - Burger Iron Co., Akron, Ohio - Grammer, Dempsey & Hudson, Inc., Newark, N. J. - Earle M. Jorgensen Co., Los Angeles-Houston-Oakland-Dallas - Passaic County Steel Service, Inc., Paterson, N. J. - Peckover's Ltd., Montreal-Toronto - Peninsular Steel Co., Detroit, Mich. - Pidgeon-Thomas Iron Co., Memphis, Tenn. - Horace T. Potts Co., Philadelphia-Baltimore-York, Pa.

Produced by W. J. Holliday & Co., Inc., Speed Steel Plate Division, Hammond, Indiana. Plants: Hammond and Indianapolis, Indiana

BRASS SINTERINGS

End High Scrap Losses on Parts Like These



Fabricated by Kwikset Locks, Inc., Anaheim, Calif.

14 costly machining and finishing operations, resulting in a 35% scrap loss, are needed to produce this aircraft brush holder from brass bar stock.

Powder metallurgy eliminates the scrap, cuts piece costs 65%—and the dimensional accuracy is the same.

This cost saving is not unusual in small cylindrical shapes, because powder metallurgy provides these design features *without machining*:

- ***Surface indents or projections on tops or bottoms of parts***
- ***Simple flanges or projections at one end***
- ***Splines, gear teeth and knurling***
- ***Holes, counterbores, slots and keyways of many shapes***

You will be interested to know, too, that generally accepted commercial tolerances for brass sinterings are .004 in. per inch on radial dimensions, and .010-.015 in. per inch on axial dimensions.

How much you can save on these and other machine parts depends on how well you know powder metallurgy as a production method. That's why you should have a copy of our new 32-page manual, "FACTS ABOUT PRESSED BRASS and other nonferrous POWDER PARTS."

It will be sent to you without obligation by the manufacturers of Horse Head® brass and other nonferrous metal powders.

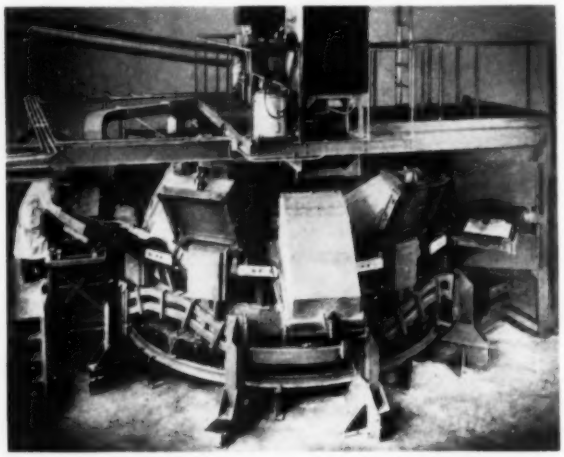
THE NEW JERSEY ZINC COMPANY
160 Front Street • New York 38, New York

treating, were inspected 100% to eliminate bearings that have not been properly hardened. Where previously it took three employees working full time to keep this test line moving at the rate of 1000 bearings an hour, now — with the metals comparator — one girl is able to do the job working part time.

For further information circle No. 965 on card, p. 32B

Automatic Shell Molding

A twelve-station unit, designed and built by Mechanical Handling Systems, Inc., will make approximately 500 shell molds per hour. The machine is automatic, requiring only one man for operation. After the pattern carriage engages the sand-resin hopper, pattern and hopper, clamped tightly together, swing forward to below the horizontal, the material falls on the pattern and the shell mold is formed. Pattern and hopper then rise, the hopper is disengaged, and the pattern carriage, with its soft shell



mold, returns to horizontal and enters the gas-fired oven, where the mold is fully cured when it emerges at the terminal station. Here the mold-release pins lift automatically, the mold is removed and the cycle starts again.

At the top of the machine is located the automatic proportioning system for sand, resin, and wetting agent. These materials are thoroughly mixed and are deposited in controlled quantity in the hoppers at each revolution of the machine.

For further information circle No. 966 on card, p. 32B

Copper Clad Steel for Conductive Spring Parts

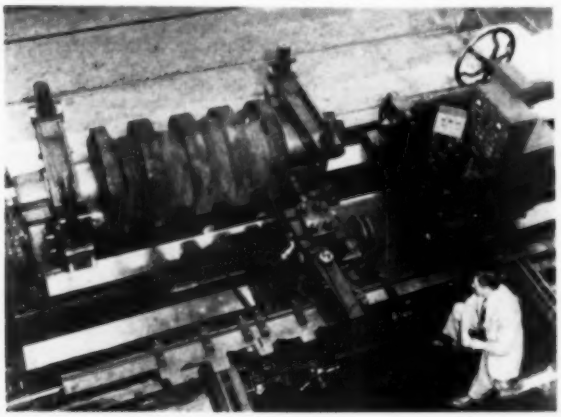
A new high conductive spring material with spring properties comparable to hardenable steel is announced by Metals & Controls Corp., General Plate Div. Conflex copper-clad hardenable steel is a composite metal consisting of a layer of medium-carbon steel with a relatively thin layer of electrolytic copper clad on one or both sides. The primary advantage of this clad steel is its low cost in comparison with hardenable copper alloys. Variation of electrical conductive properties is obtained by varying the thickness of the copper layers; a 10/80/10 thickness ratio has conductivity better than 30% of standard copper.

For further information circle No. 967 on card, p. 32B

Automatic Machining of Contour Rolls

Fully automatic contour duplication is accomplished on a 60-in. roll-turning lathe recently installed in U. S. Steel's Homestead, Pa., roll shop. For the first time on a machine tool of this size, all-electronic duplicating equip-

ment is used to control the tool's cutting action and to generate the complex outlines which produce beams, channels, ship sections and other rolled steel products. The duplicating device guides the motion of the cutting tool from a flat template whose contours are exactly those of the roll to be machined. Signals from the floating tracer



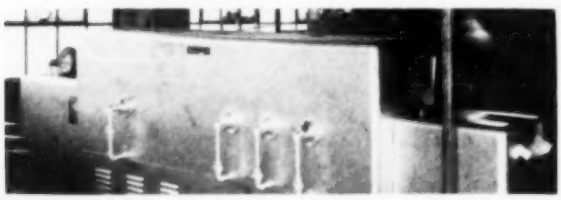
stylus are electronically amplified, interpreted and fed to two electric motors. The combined action of the motors in response to the signals keeps the stylus travelling and hugging the template. Since the cutting tool is mounted on the same movable part of the lathe carriage as the stylus, tool travel duplicates the path of the stylus.

Mackintosh-Hemphill Co., designer and builder of the lathe, expects it to effect substantial savings in time and money, machining complex steel mill rolls accurately and quickly. At the Homestead roll shop, on one type of roll used to produce structural shapes, the lathe reduces estimated roughing and finishing time from 156 to 49 hr.; on another from 196 to 49 hr. Rate of metal removal, discounting setup time, ranges from 2 to 1 to 6 to 1, contour lathe vs. standard lathe. This naturally depends on the roll material, which may be cast iron, carbon steel or alloy steel. Using carbide tools, the unit turns at headstock spindle speeds up to 32 rpm. A standard roll turning lathe, working with high speed tools under comparable conditions on the same roll material, would be able to remove metal at spindle speeds between 1 and 4 rpm. Present practice on the new lathe calls for surface speeds of about 60 ft. per min. on iron and 200 on steel.

For further information circle No. 968 on card, p. 32B

Continuous Annealing Brass Stampings

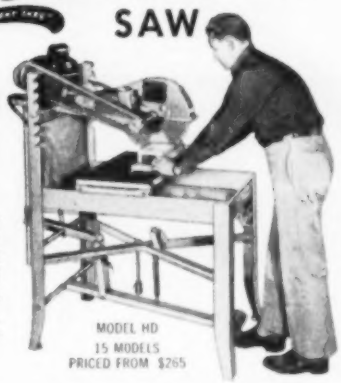
The Waltz continuous furnace shown below is used for annealing brass stampings between draws. The furnace is gas-fired by eight burners with individual mixers. Combustion blower, control valve, gas regulator and variable-drive mechanism are mounted within the casing.



A small rubber-tired wheel, shown at the extreme left, presses the belt against a large ball-bearing-mounted idler-pulley to drive the belt. This type of furnace can be built for many different applications, either open fired or controlled atmosphere, full muffle type.

For further information circle No. 969 on card, p. 32B

Clipper MASONRY SAW



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60-cycle **induction**

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THIS Loftus Universal Thermo-Induction furnace is the most flexible 60-cycle billet heater ever designed. You can heat every non-ferrous metal, in the same furnace, either consecutively or simultaneously, to its respective forging or extrusion temperature. The unit maintains high efficiency, constantly, even when heating **short-length** billets.

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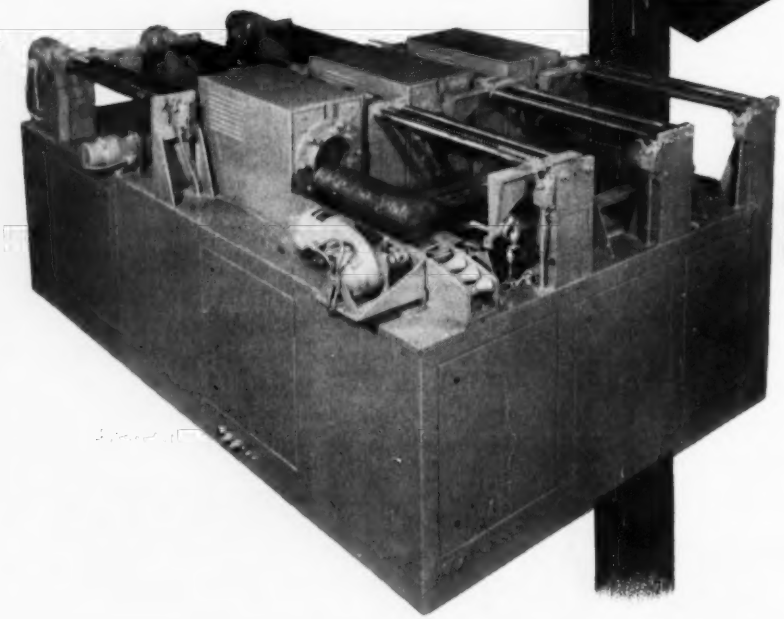

The Loftus 60-cycle Thermo-Induction Heater illustrated is designed to heat copper, brass, aluminum, and cupro-nickel for extrusion purposes. The unit is readily adaptable for forging and rolling processes. It is possible, with this billet heater to heat a 5" dia. Aluminum billet to 800° F., an 8" dia. brass billet to 1550° F., and a 10" dia. cupro-nickel billet to 1950° ALL AT THE SAME TIME, IN THE ONE FURNACE. Each billet is heated independently . . . from a single control panel.

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970. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

971. Acid Descaling
Bulletin on Descaler 2A for carbon and alloy steels. *Enthone*

972. Air-Gas Mixer
Bulletin L-700 gives engineering and application data on air-gas proportional mixer. *Eclipse Fuel Engineering*

973. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

974. Alloy Castings
Property data for 21% Cr, 9% Ni heat-resistant alloy. *Electro-Alloys Div.*

975. Alloy Castings
16-page Booklet 112 on alloy castings for furnace applications. Design stresses vs. temperature. *Michiana Products*

976. Alloy Selection
Chart to select alloy for given corrosive problem. 350 corrosives included. *Cooper Alloy Foundry*

977. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

978. Alloy Steel
68-page "Aircraft Steels" booklet includes revised military specifications. Also stock list. *Ryerson*

979. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

980. Aluminum Bronze
Data sheets for aluminum bronze coated electrodes for metal-arc welding. *Weldwire*

981. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

982. Aluminum Extrusions
Data on services in the field of aluminum extrusion. *Himmel Bros. Co.*

983. Aluminum Heat Treating
8-page Bulletin 5912 on solution heat treating, annealing, stabilizing and aging of aluminum. *General Electric*

984. Ammonia Atmospheres
Bulletin B-52 on dissociated ammonia for furnace atmospheres. *Drever*

985. Ammonia for Heat Treat
Booklets on "Applications of Dissociated Ammonia", "Ammonia Installations for Metal Treating", "Nitriding Process", "Carbonitriding". *Armour*

986. Analysis
Article on use of spectrometer for 800 detn. per day at Weirton Steel. *Baird*

987. Analysis
12-page Bulletin i-5 on analysis with grating spectrographs. *Jarrell-Ash*

988. Analysis of Nickel Alloys
52-page Technical Bulletin T-36, "Methods for Chemical Analysis of Nickel and High-Nickel Alloys". *International Nickel*

989. Anodizing
Bulletin on racks for anodizing, bonderizing, electropolishing and plating. *New England Rack*

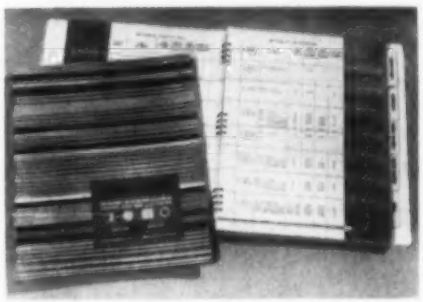
990. Anodizing
Data on aluminum racks with copper hooks for anodizing. *National Rack*

991. Atmosphere Furnaces
Information on gas-atmosphere high-production furnace for bright annealing of copper alloys. *Holcroft*

992. Atmosphere Furnaces
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

993. Atmospheres
8-page Bulletin SC-155 discusses following controlled atmospheres: RX, DX, NX, HNX, AX, HX. Compositions, applications, effects on steel, drawings of generators. *Surface Combustion*

994. Aluminum Extrusions



This 98-page book is one of the most complete in the extrusion field. It is intended to assist designers, engineers and purchasing men in the selection of the exact extrusion for particular applications. Engineering and design data are given for the 14 aluminum alloys most frequently used in extruded form. Data include temper, least thickness to be worked, strength and elongation. Over 4000 standard extruded shapes and sizes are listed, with isometric drawings of the intricate shapes. *Precision Extrusions*

995. Atom Models
12-page booklet on construction of scale models of atomic crystal structures. *Fisher Scientific*

996. Band Saws
12-page Bulletin G52 horizontal metal cutting band saw machines. Reference chart for selection of blade, feed, speed. *Wells Mfg. Corp.*

997. Bar and Tube Turners
16-page bulletin on centerless turners for round bars and tubes. *Medart*

998. Barrel Cleaning
8-page Bulletin 218 on continuous automatic barrel cleaning. *Pangborn*

999. Barrel Finishing
22-page book on single-unit installation to yield savings up to 95% in finishing various parts. *Almco Div.*

1000. Bending
Catalog on presses for bending, forming, blanking, drawing and multipunching. *Cleveland Crane & Engineering*

1001. Bending Aluminum
Bending formulas and radii for 90 and 180° cold bending of various grades and tempers of aluminum. "Technical Advisor No. 18". *Reynolds Metals*

1002. Bending and Forming
8-page bulletin on hydraulic bulldozers for hot and cold bending and forming operations. *Lake Erie Eng.*

1003. Beryllium Copper
Helpful engineering information contained in monthly beryllium copper technical bulletins. *Beryllium Corp.*

1004. Bimetal Applications
32-page book on application of thermostatic bimetal. Property charts for 30 types. Design formulas. *W. M. Chace*

1005. Black Oxide Finish
Folder on penetrating black finish for ferrous metal. *Puritan Mfg.*

1006. Black Oxide Finish
Bulletin on dip process for putting black oxide finish on ferrous metal. *Special Chemicals*

1007. Black Oxide Finish
Four-page article "Low-Cost Black Oxide Finish on Steel by Chemical Dip Method". *Mitchell-Bradford*

1008. Blower
Bulletin K-100 on centrifugal blower for all types of combustion equipment. *Eclipse*

1009. Boron Nitride
Data Sheet 513B on properties and possible uses of boron nitride. *Norton*

1010. Braze-Carburize
Article on simultaneous brazing and carburizing of hand tools. *Ajax Electric*

1011. Brazing Applications
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

1012. Brazing Stainless Steel
Illustrated booklet, "Bright Annealing, Hardening and Brazing Stainless Steel", describes conveyor furnace and bright brazing alloy. *Sargeant & Wilbur*

1013. Brazing Steel Tubing
Bulletin TB 349 on setting up tube brazing operation. *Babcock & Wilcox*

1014. Brazing Titanium
Data sheet on use of a new flux for brazing titanium. *Handy & Harman*

1015. Bright Carburizing
Job data on bright carburizing and hardening gears. *Ipsen*

1016. Burners
16-page bulletin on selection of gas burners. *Western Products*

1017. Burners
Bulletin on combination gas and oil burner. *Ra-Diant Products*

1018. Carbide
Brochure describes sintered chromium carbide for gage blocks. *Firth Sterling*

1019. Carbide Coatings
12-page Bulletin 8065, "Flame Plating", on method of applying tungsten carbide coatings. Comparative wear test data. Applications. *Linde*

1020. Carbide Tools
Performance report on carbide drill, boring bar and reamer. *Willey's Carbide*

1021. Carbides
56-page Catalog 441 on carbide blanks and tools; 12 pages of technical data. *Vascoloy-Ramet*

1022. Carbides
16-page catalog of carbide blanks, inserts and tools; 5 pages of technical data on applications. *Newcomer*

1023. Carbides
64-page catalog 52 gives latest information on carbide tooling. Completely illustrated details on all types of cutting tools. Handy tables for grade selection and cutting speeds. *Kennametal*

1024. Carburizing Salts
Folder on salts for liquid carburizing. *Swift Industrial Chemical*

1025. Casting Specifications
Design values for five grades of heat resistant castings. *Ohio Steel Foundry*

1026. Castings, Bronze
16-page booklet on sand and centrifugal castings. *Amer. Non-Gran Bronze*

1027. Chemical Instruments
Catalog of mass spectrometers, leak detectors, other instruments. *Consolidated Engineering*

ZIV TOOL STEEL REPORT

(Darwin & Milner's PRK-33 COBALTCROM)

DATE Jan. 10, 1953

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STREET 2000 Hanley Road

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TALKED WITH	PRICES QUOTED
Superintendent	############

REMARKS

In April of 1944, they ordered PRK-33 rings which were machined into Lead Pencil Headers. This is a cylinder slotted lengthwise and each slot contains a lead pencil. At the ends of the cylinder PRK rings are installed and against these PRK facings a circular knife revolves and trims the end of lead pencils. The paint on these pencils is very abrasive and ordinary tool steels used on these facings wear rapidly.

These facings were formerly ground 12 to 18 times per year and each grinding meant tearing the machine down and interrupting production and then setting up and readjusting.

Introduction of PRK has saved them time and money. These facings are still in service since about the middle of 1944, and although running continuously day in and day out they have only been ground twice and on one occasion the grinding was not due to wear but rather due to grooving action of a misaligned cutter.

SALESMAN

ZIV STEEL & WIRE CO.

2945 W. HARRISON ST. CHICAGO, ILLINOIS

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1028. Chromate Coatings
Folder gives characteristics and uses of chromate conversion coatings on nonferrous metals. *Allied Research*

1029. Cleaning
12-page bulletin on washing and drying machines; conveyor, cabinet, drum and vertical types. *Industrial Systems*

1030. Cleaning
20-page pocket-size book on electrolytic and nonelectrolytic cleaning, tumbling, paint stripping. *Magnuson Prod.*

1031. Cleaning
12-page Bulletin 68 deals with factors to consider in selecting metal cleaning equipment. *Despatch Oven*

1032. Cleaning
20-page bulletin 214 gives performance on Rotoblast cleaning. *Pangborn*

1033. Cleaning Aluminum
Set of seven data sheets on cleaning and finishing of aluminum. *Pennsalt*

1034. Cleaning Equipment
Folder on degreaser. Data on different models. *Topper Equipment*

1035. Cleaning Stainless
Guidebook on cleaning of stainless steel and nickel alloy equipment. *Lukens*

1036. CO_2 as Coolant
Bulletin on use of a jet of liquid carbon dioxide directed at point of contact between cutting tool and work to keep both cool. *Pure Carbonic Co.*

1037. Cold Heading Brass Wire
"Cold Heading Extruded Brass and Copper Wire" gives physical and fabrication properties, applications, lb. per 1000 ft. and ft. per lb. *Chase Brass*

1038. Combustion Control
20-page booklet on combustion of various fuels and portable instrument to measure content of oxygen and combustibles. *Cities Service Oil*

1039. Composition Chart
Composition ranges of 60 types of metals in 10 classes. *Sam Tour & Co.*

1040. Compressors
12-page data book 107-C gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1041. Continuous Forging
12-page reprint on automatic rotary furnace applied to continuous forging system at Dodge. *Geo. J. Hagan Co.*

1042. Controlled Atmospheres
24-page bulletin describes production problems with reference to dry atmospheres. *Pittsburgh Lectrodryer*

1043. Controllers
56-page Catalog 1530 on electric and pneumatic controllers. *Minneapolis-Honeywell*

1044. Core Oils
Bulletin on core oils for foundry. *Swan-Finch*

1045. Corrosion Control
6-page article on Nielizing process for producing completely clean, nonactive surface on ferrous metal. *Nielco Labs.*

1046. Corrosion-Proof Tanks
Bulletin 9-1 on properties and uses of new corrosion-proof plastic for tanks, dipping baskets, exhaust systems. *Atlas Mineral Products*

1047. Crystal Models
Folder describes unique kit for constructing crystal models. *Harshaw*

1048. Cutting Fluids
16-page booklet on selection of cutting fluids, testing procedures, machinability. *Pure Oil*

1049. Cutting Machinery
Brochure on high-speed cutting machinery and wheels. *Stone Machinery*

1050. Cutting Oil Chart
Selection chart for seven classes of metal in nine machining operations. *Aldridge Industrial Oils*

1051. Cutting Oil System
Data and charts on new cutting oil, dispensing jet and motor-driven pump. Test results of overhead flood with conventional coolants vs. jet. *Gulf Oil*

1052. Deep Drawing Titanium
"Pioneering the Deep Drawing of Titanium", by J. Walter Gulliksen. *Worcester Pressed Steel Co.*

1053. Degassing Copper Alloys
Bulletin on use of copper oxide to prevent formation of hydrogen gas in copper alloy castings. Comparison of six methods to maintain oxidizing conditions during melting. *Glidden Co.*

1054. Degreasing
Bulletin on aromatic type of safety degreaser. *Curran*

1055. Degreasing
24-page brochure on medium-pH cleaner to follow solvent degreasing or other precleaner. *Northwest Chemical*

1056. Descaling Process
8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *Du Pont*

1057. Desulphurization
20-page reprint ADR 81 on calcium carbide injection gives data on application to molten cast iron. *Air Reduction*

1058. Diamond Abrasive
4-page folder on the advantages of diamond abrasives for polishing metallurgical specimens. *Buehler Ltd.*

1059. Die Casting
Bulletin on 1-lb. capacity die-casting machines for zinc and aluminum. *DCMT Sales*

1060. Drawing Compounds
Folder on lubricant for forming and drawing of stainless. *Hangsterfer*

1061. Drawing Lubricant
8-page bulletin on dry lubricant for drawing, forming, extrusion; also equipment for applying lubricant to sheets. *Gilron Products*

1062. Ductile Iron
New list of publications available on advantages and properties of ductile iron, along with special applications and 100 authorized foundry sources now producing it. *International Nickel*

1063. Electric Furnaces
Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

1064. Electric Heaters
64-page Bulletin 1005D on Calrod electric heaters and heating devices. *General Electric*

1065. Electric Melting
Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

1066. Electroforming
Bulletin on production of intricate parts and precision components by the electroforming process. *Bart Labs.*

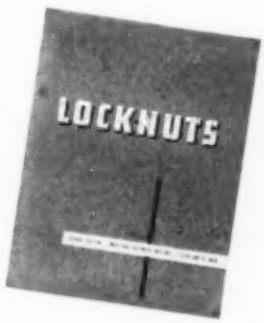
1067. Fabric Tester
Bulletin 652 on portable instrument for testing fabric on the airplane. *Steel City Testing Machines*

1068. Fabrication Data File
Reference file of engineering information about equipment and processes used for stampings, heavy weldments and pressed steel shapes. *Brandt*

1069. Fans
16-page Bulletin 6001 on fans for exhaust hoods, recirculating cold air in subzero freezers and other applications. Detailed tabular data on performance. *Robinson Ventilating*

1070. Stainless Fasteners
Slide-chart selector, in terms of AN specification numbers, gives data for nuts, screws, rivets, cotter pins, washers, all of stainless steel. *Anti-Corrosive Metal Products Co.*

1071. Set Screws
20-page catalog-reference book on set screws. *Set Screw & Mfg. Co.*



1072. Locknuts
24-page brochure is a guide to selection. Descriptions are given of 36 representative types of locknuts made by 21 manufacturers. *Industrial Fasteners Institute*

1073. Bolt Assemblies
40-page Engineering Folder S-49 on screw or bolt and washer assemblies. *Reliance Div., Eaton Mfg.*

1074. Fastening Specialties
22-page Catalog B2 on screw fasteners, blind rivets, adjustable pawl fasteners, spring-grip fasteners, anchor nuts and other fastening specialties. *Southco Div.*

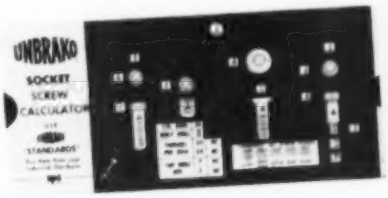
1075. Threaded Blind Rivets
20-page data book for designers and engineers. Selection and applications of one-piece blind rivets with threads. Engineering and assembly data. *B. F. Goodrich*

1076. Nonferrous Fasteners
56-page stock book for complete line of fastenings in brass, bronze, copper, Monel, aluminum and stainless steel. *H. M. Harper Co.*

1077. Stainless Fasteners
Detailed catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fittings and specialty items. *Star Stainless Screw Co.*

1078. Screw Thread Inserts
16-page book of design data and specifications on screw thread bushings of helically coiled wire, for aluminum, magnesium, iron, steel, plastics or wood. Extensive tabular data and installation guide are included. *Heli-Coil Corp.*

1079. Rivet Setting
Operating instruction manual includes detailed information on the operation of automatic rivet-setting machines. *Milford Rivet & Machine Co.*



1080. Socket Screws
Pocket-size slide calculator. Set the slide for the screw diameter at top and read below the threads per inch and tap drill size in National Coarse and National Fine series, and the body drill and counterbore sizes; also all other dimensions for five types of screws and the thread pressure plug of the given diameter. Reverse side lists decimal equivalents of all drill sizes from No. 80 to one inch. *Standard Pressed Steel*

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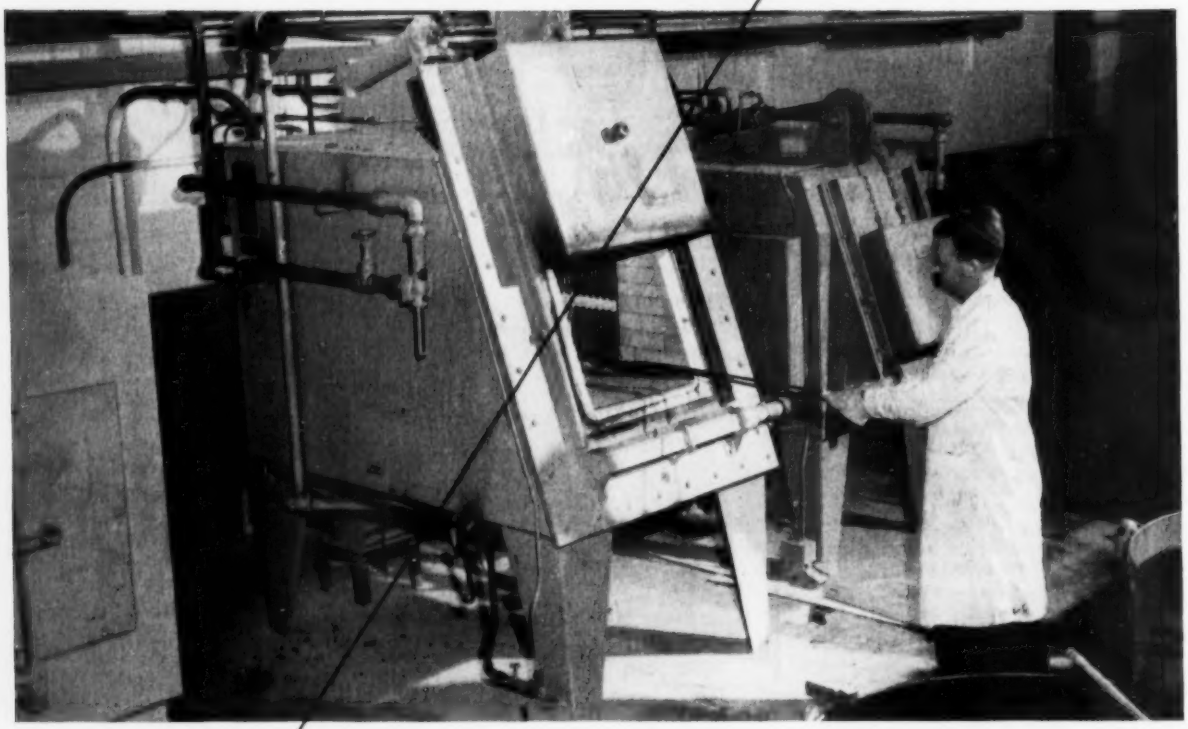
HEAT TREAT ORENDA TURBOJET ENGINE PARTS



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Proof of this is the fact that A. V. Roe (Canada) Ltd., in their new multi-million dollar aircraft plant, use Lindberg furnaces to heat treat parts for the world famous Orenda Turbojet engines.

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Lindberg Furnaces can solve your heat treating problem, too, from the touchiest tool and die job . . . to huge production jobs involving the hardening or tempering of tons of work daily. For descriptive literature contact your nearest Lindberg office.

Bulletin *96hs* covers the type of furnaces used in the A. V. Roe plant

LINDBERG FURNACES

Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois

1081. Finishing
28-page catalog B-9 on corrosion-resistant baskets, racks, crates and tanks and other fixtures for cleaning and finishing. *Rolock*

1082. Finishing
Six bulletins describing finishing compounds for stainless steel, aluminum, other metals. *Apothecaries Hall*

1083. Cutting Fluids
This slide chart simplifies the calculation of cutting fluid dilution. Set arrow at dilution required and read gallons of oil required opposite tank capacity. Volume equivalents and other data are given on the back. *D. A. Stuart Oil Co.*

1084. Finishing Aluminum
Brochure "How To Cut Die-Casting Finishing Costs" deals with aluminum castings. *Monarch Aluminum*

1085. Flaw Detection
Information on electronic equipment for nondestructive inspection of regular and irregular iron and steel parts. *Magnetic Analysis Corp. (Foerster)*

1086. Flaw Detection
12-page bulletin on location of flaws by two dye-penetrant inspection methods. *Turco Products*

1087. Flow Meter
Data Sheet 10.3-5 on electronic flow meter for liquids and gases. *Minneapolis-Honeywell*

1088. Flow Meter
Bulletin on gas flow meter for furnace installations. *Hays Corp.*

1089. Flow Meters
12-page Bulletin 2M50 on mechanical flow meters that give high accuracy at low flows. *Hagan Corp.*

1090. Flow Meters
Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng.*

1091. Flow Meters
Bulletin 460 on complete line of flow meters, indicators, recorders, controllers, transmitters. *Foxboro*

1092. Flow Meters
Catalog on meters and accessories for measuring pressure and vacuum of liquids and gases. *Meriam Instrument*

1093. Forgeability
112-page book, "Evaluating the Forgeability of Steels". Hot work characteristics in chart form for 94 steels. *Timken*

1094. Forging Manipulators
Folder on manipulators for automotive, ordnance, aluminum and specialty forging. *Salem-Brosius*

1095. Forgings
Handsome 32-page brochure on large forgings for turbine shafts, rotors, drop hammer anvils, rolls. *U. S. Steel*

1096. Forgings
20-page Catalog 51 on various types of forgings, their strength and related data. Tables, drawings. *Merrill Bros.*

1097. Forming Dies
Data on roller dies for forming tubes and rolled shapes. *American Roller Die*

1098. Foundry
36-page illustrated booklet dealing with foundry products, procedures and craftsmanship. *Lebanon Steel Foundry*

1099. Foundry Abrasives
Booklet 4 on seven uses of abrasive products in foundry. *Abrasives Div., Carborundum*

1100. Foundry Alloys
24-page book on briquetted alloys for iron foundry. *Electro Metallurgical*

1101. Foundry Coatings
Data on colloidal graphite for mold washes, pattern coatings, core coatings, chill coatings. *Acheson Colloids*

1102. Foundry Costs
Engineering and cost analysis of core baking equipment. *Induction Heating*

1103. Foundry Practice
Article on gates and risers with reference to nonferrous practice. *R. Lavin*

1104. Foundry Resin
12-page Bulletin 224 on phenolic resin for use as a core sand binder. Complete data. *Chemical Div., General Electric*

1105. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1106. Furnace Construction
12-page bulletin on thin-wall construction for furnace enclosures. Engineering drawings. *Bigelow-Liptak*

1107. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood Corp.*

1108. Furnace Heating
32-page bulletin on silicon carbide recuperator for open hearth, air furnace, soaking pits, pipe welding, slab heating, billet heating, and armour plate heating. Fuel savings charted. *Fitch Recuperator*

1109. Furnaces
Bulletin HT-53 on furnaces for heat treating, other applications. *Carl-Mayer*

1110. Furnaces
Booklet 127 on furnaces, ovens, dryers, and special automatic machines for industry. *Continental Industrial Engineers*

1111. Furnaces
Bulletin 435 describes new furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

1112. Furnaces
16-page booklet "Proven Heat Treating Efficiency" displays complete line of furnaces. *Loftus Engineering*

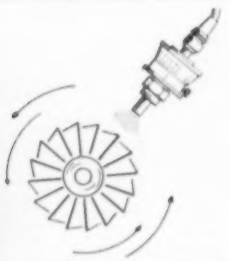
1113. Furnaces
44-page Catalog 112, well illustrated, features furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating. Also atmosphere generators and ammonia dissociators. *C. I. Hayes*

1114. Furnaces
Bulletin describes 18 electric furnaces for research and small-scale production, with operating temperatures to 3000 F. *Harper Electric Furnace*

1115. Furnaces, Annealing
Folder of performance and cost data on radiant tube and roller hearth furnaces. *Gas Machinery*

1116. Furnaces, Heat Treating
Bulletin on furnaces for annealing,

ALSO MEASURES • Motor vibration, valve travel, bounce • Shaft whip • Acceleration • Eccentricity of commutators, slip rings • Vibration in heat exchangers



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normalizing, hardening, tempering, forging. *Flinn & Dreffein Engineering*

1117. Furnaces, Heat Treating
12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

1118. Furnaces, Heat Treating
Catalog on furnaces for tool room and general-purpose heat treat. *Cooley*

1119. Furnaces, Heat Treating
Bulletin on fuel and electric furnaces for heat treating. *Dempsey*

1120. Galvanizing
Reprint "Modern Hot-Dip Galvanizing" deals with dross formation as a cause of zinc waste. Detailed information on zinc ammonium chloride type of flux. *Hanson-Van Winkle-Munning*

1121. Galvanizing
Article on hot dip galvanizing of evaporators at Frost Co. *Sunbeam*

1122. Globar Furnaces
Bulletin 153 describes nine types of furnace using silicon carbide heating elements for temperatures to 2600° F. *Hevi Duty*

1123. Hardfacing
40-page Hard-Facing Manual tells what metals can be hardfaced, how to select right hardfacing material, lists step-by-step procedures and industrial applications. *Haynes Stellite*

1124. Hardfacing
22-page "Handbook of Hard Facing Applications for Maintenance of Equipment in Iron and Steel Plants". *Stoody*

1125. Hardness Conversion
Wallet-size celluloid card gives hardness and tensile conversions. *International Nickel*

1126. Hardness Numbers
Pocket-size table of Brinell hardness numbers incorporating other tabular information. *Steel City Testing*

1127. Hardness Tester
Bulletin on production hardness tester that can make up to 900 tests per hour. *Testing Equipment Co.*

1128. Hardness Tester
Bulletin ET 407 on new portable hardness tester. *Newage International*

1129. Hardness Tester
4-page bulletin on Brinell hardness tester weighing 26 lbs. for portable and stationary use. *Andrew King*

1130. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1131. Hardness Tester
Literature on Brinell testing machines. *Detroit Testing Machine Co.*

1132. Heat Treat Furnaces
Bulletin 96hs on toolroom and production heat treat furnaces. *Lindberg*

1133. Heat Treating
12-page bulletin on heat treating in a steam atmosphere. *Leeds & Northrup*

1134. Heat Treating
Bulletin 850 on shaker-hearth furnace for bright carburizing, carbonitriding, hardening. *Hevi Duty Electric*

1135. Heat Treating Aluminum
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

1136. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div., Allied Chemical & Dye*

1137. Heat Treating Stainless
84-page book on heat treating stainless steels, both martensitic and austenitic. *Republic Steel*

1138. Heaters
20-page bulletin on immersion heater for plating, cleaning, finishing and quenching tanks. 12 case histories. *Kold Hold Mfg.*

1139. Heating Elements
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

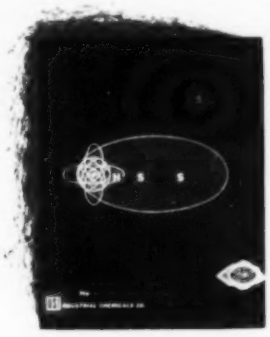
1140. Heating Method
16-page reprint on uses of immersion gas heating. *Dewey Gas Furnace*

1141. High-Alloy Castings
28-page "Ni-Cr Castings to Resist Heat & Corrosion". *Standard Alloy*

1142. High-Temperature Alloys
High temperature work sheet provides valuable suggestions for solving high temperature problems in design and production. *International Nickel*

1143. High-Temperature Fans
Bulletin 645 on fans for use at temperatures to 1800° F. *Michiana Products*

1144. Sodium Metal
This 24-page book deals with "high-surface" sodium – that is, sodium in colloidal form, spread



over inert solids of high surface area. One of the applications discussed is the reduction of such metals as titanium, zirconium and silicon. Desulphurization and deoxidation of steel would seem to be possibilities also. *U. S. Industrial Chemicals Co.*

1145. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

1146. Hydride Descaling
24-page book "Handling Metallic Sodium" with special reference to sodium hydride descaling. *U. S. Ind. Chem.*

1147. Induction Heat Control
Data sheet on radiation pyrometer for direct measurement of work being induction heated. *Leeds & Northrup*

1148. Induction Heating
Bulletin on low-frequency (60 cycle) induction heating furnace for nonferrous metals. *Magnethermic*

1149. Induction Heating
Catalog MP-2 describes portable high frequency induction heating unit for brazing, hardening, soldering, annealing and melting. *Lepel High Frequency*

1150. Induction Heating
12-page bulletin 5679 on induction hardening, brazing, annealing at 1000, 3000, and 10,000 cycles. *General Electric*

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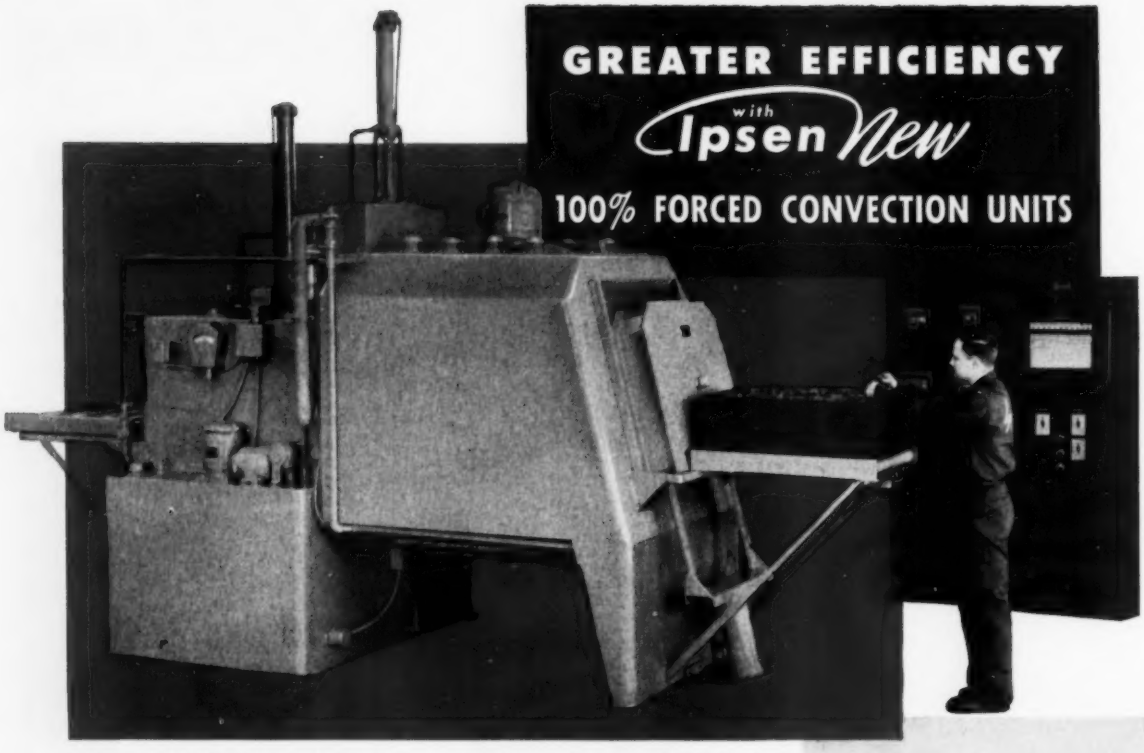

▲ *New Ipsen 400 Lb./Hr. Automatic Heat Treating Unit equipped for martempering. Straight-through operation from heat through quench, or cooling, eliminates loading delays.*

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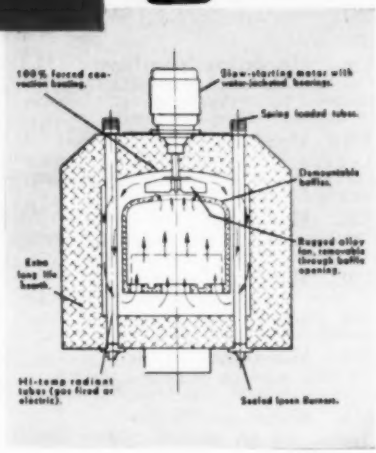
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4 **Demountable Baffles** — assure complete circulation of atmospheres through the load and maintain uniform work temperature. Sectional-type construction permits easy replacement. Complete unit can be removed in ten minutes.

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"Induction Heating"...presents case histories of increased production, reduced space, lower costs. *Westinghouse*

1152. Induction Heating
60-page catalog tells of reduced cost and increased speed of production on hardening, brazing, annealing, forging or melting jobs. *Ohio Crankshaft*

1153. Induction Heating
Book contains selector chart and heating and melting speeds for induction equipment. *Ajax Electrothermic*

1154. Industrial Finishing
Catalog A-653 gives complete story on planning industrial finishing systems and shows many installations of cleaning and pickling machines. *R. C. Mahon*

1155. Infra-Red Heating
20-page bulletin on infra-red heating for drying, degreasing, dehydrating, preheating and other applications. *Fostoria Pressed Steel*

1156. Inspection
Illustrated bulletin on Spotcheck, new dye-penetrant method for locating surface defects. *Magnaflux*

1157. Inspection Stamps
28-page Catalog 100 of inspection, symbol, letter and figure stamps, steel type, special marking outfits. *M. E. Cunningham Co.*

1158. Instruments
20-page Catalog 1053 on millivoltmeter-type instruments for indicating, electronic control and safety shut-off. *Minneapolis-Honeywell*

1159. Insulating Brick
Bulletin on fire brick and sil-o-cel insulating brick. *Johns-Manville*

1160. Ion Exchange
Data and specifications on monocolumn demineralizers using ion-exchange method. *Penfield Mfg. Co.*

1161. Laboratory Furnaces
Data sheets on complete line of laboratory furnaces for metallurgical operations. *Boder Scientific*

1162. Lubricants
Bulletin on complete line of molybdenum disulphide lubricants. *Bel-Ray*

1163. Machining Nickel Alloys
40-page Bulletin T-12 on machining wrought and cast nickel alloys. *International Nickel*

1164. Magnesium Finishing
128-page book describes all methods for finishing magnesium. *Dow Chemical*

1165. Magnetic Alloys
20-page bulletin on the more important "magnetically soft" iron-nickel alloys. *International Nickel*

1166. Marking Tools
32-page bulletin on marking stamps and dies. *Parker Stamp Works*

1167. Master Alloys
24-page book on alloys for adding to ferrous and nonferrous melts. *Alter Co.*

1168. Melting
24-page book on electric furnaces for steel mills and foundries. Table of types, sizes, ratings. *American Bridge*

1169. Melting Furnaces
8-page Bulletin 560 describes stationary and tilting types of two-chamber melting furnaces. Applications to all types of casting. *Lindberg Engineering*

1170. Metal Recovery
9-page reprint, "Metal Recovery by Ion Exchange". *Permutit Co.*

1171. Metallograph
Bulletin on the Unitron universal camera microscope. *United Scientific*

1172. Metallograph
Metallograph, described in catalog E-240, furnishes four different accurate images of same sample for complete identification with bright field, dark field or polarized light. *Bausch & Lomb*

1173. Metallographic Polishing
Booklet describes line of two-speed polishers. *Buehler Ltd.*

1174. Modulus Determination
Data sheet on equipment for determination of modulus of elasticity by sonic method that measures resonance frequency of masses weighing up to 1500 lb. *Electro Products Laboratories*

1175. Moly-Sulphide Lubricant
40-page booklet on Moly-sulphide lubricant gives case histories for 154 different uses. *Climax Molybdenum*

1176. Nickel Alloys
40-page book gives corrosion, physical and mechanical properties of Hastelloy alloys; 13 pages of fabrication data. *Haynes Stellite*

1177. Nickel Plating
12-page reprint, "Mechanical Properties of Nickel Deposits", deals with effects of plating variables on properties. 13 charts, 3 tables, 40 micrographs. *International Nickel*

1178. Nondestructive Testing
Data on equipment for inspection and sorting. *Magnetic Analysis*

1179. Nonferrous Tubing
Bulletin on seamless, brazed and lock-seam tubing in brass and copper. *H & H Tube and Mfg.*

1180. Oil Quenching
Catalog V-1146 on self-contained oil cooling equipment. Selection tables for volume of oil required and oil recirculation rates. *Bell & Gossett*

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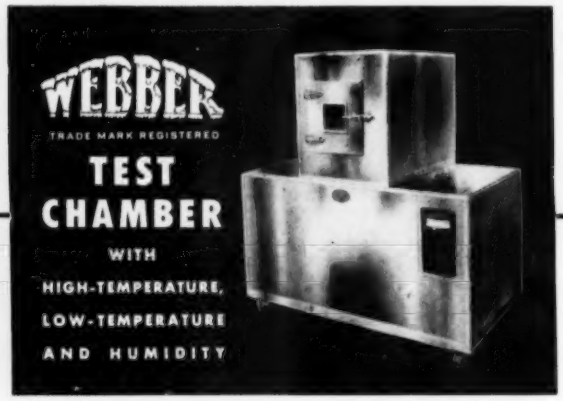

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1183. Oxygen-Nitrogen Generators
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1184. Peening
Bulletin on use of cut wire shot for peening and cleaning. *Park Chemical*

1185. Phosphate Coating
12-page "Phosphate Coating Chemicals and Processes" gives data on paint bonding, rust proofing, protecting friction surfaces, improving drawing and extrusion. *American Chemical Paint*

1186. Pickling
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1187. Pickling
80-page book "Efficient Pickling" covers all variables of process. Many charts and tables. *American Chemical Paint*

1188. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1189. Pit Furnace
Bulletin 294 on ingot heating pit furnace. Performance data, drawings, amortization chart. *Amsler Morton*

1190. Plating
Set of bulletins on filtration equipment for plating solutions. *Sparkler*

1191. Portable Hardness Tester
Bulletin on portable Brinell-type tester weighing 19 lb. *Blosjo Enterprises*

1192. Portable X-Ray Unit
Bulletin on 250,000-volt industrial X-ray unit weighing less than 150 lb. *X-Ray Dept., General Electric*

1193. Potentiometers
Article gives technical data on semi-precision potentiometers. *Rubicon*

1194. Powder Metallurgy
32-page handbook gives 24 case histories of parts designed or redesigned for powder metal production. Cost comparisons; definitions of terms and list of standards. *New Jersey Zinc*

1195. Precision Castings
8-page bulletin on design and engineering factors of precision castings. *Sessions Foundry Co.*

1196. Precision Forgings
Data folder on small metal parts forged to within a few thousandths. *Utica Drop Forge*

1197. Precision Measurement
Bulletin on granite surface plates of accuracy to 0.00005 in. *Lawley*

1198. Pre-Finished Metals
16-page fabrication handbook on preplated metals, ferrous and nonferrous. *American Nickeloid*

1199. Process Equipment
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

1200. Punching and Shearing
Bulletin 347 on combination shear, punch and coper. Data on capacities. *Kling*

1201. Quenching
Bulletin 820 on automatic quenching tanks for use with continuous heat treat equipment. *Am. Gas Furnace*

1202. Quenching
Bulletin 120 on use of heat exchangers

(Continued on p. 32-A)

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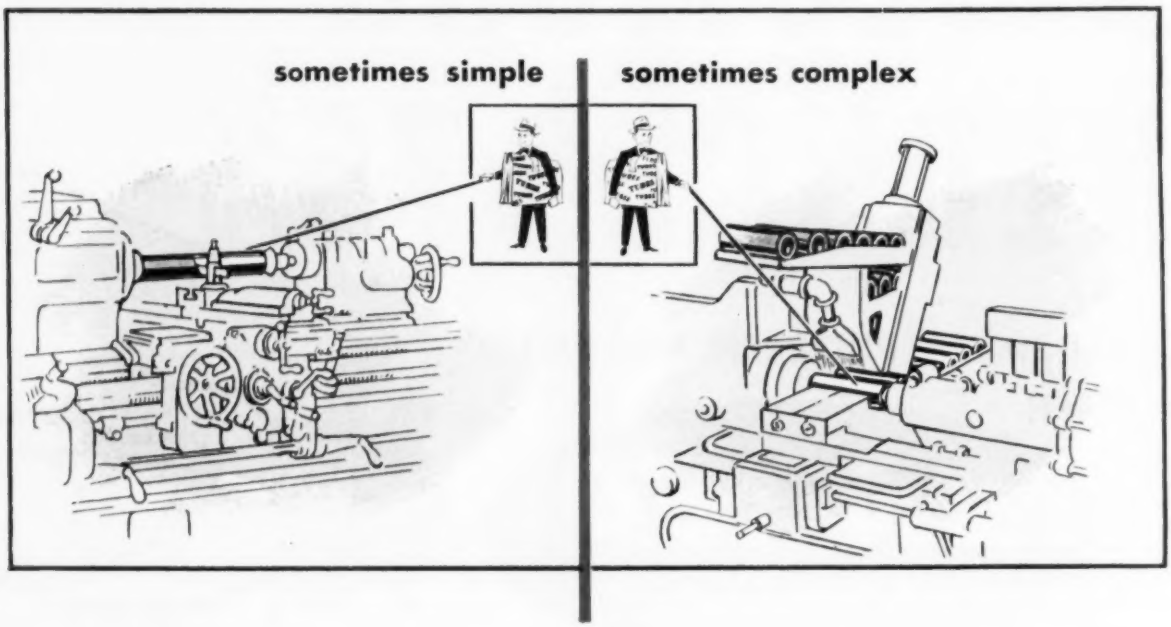
Machinability of Tubing



requiring . . .

Much can be said about the comparative machinability of these three types of seamless mechanical tubing. What is best for one user is not always best for another user. For example —B&W is supplying mechanical tubing to three different manufacturers who are producing the same piece of equipment — one from Hot-Finished tubing, the second from Cold-Drawn tubing, and the third from Roto-Rocked tubing. The real criterion for machinability rests with the user and how he is equipped to produce the part.

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TUBULAR PRODUCTS DIVISION
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for control of temperatures and other process variables

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Designed to satisfy the need for close limit temperature control, Wheelco Capacitrol with built-in Capaciline provides a low-cost equivalent of proportioning control. Speeds production . . . reduces waste in fuel and materials . . . assures maximum uniformity of product.

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1225 ROCK STREET • ROCKFORD, ILLINOIS, U.S.A.

(Continued from p. 30)

to provide heat control in quenching bath. *Niagara Blower*

1203. Radiography
Bulletin 400-310 on self-contained X-ray unit for mass production inspection of parts. *Westinghouse*

1204. Radiant Tubes
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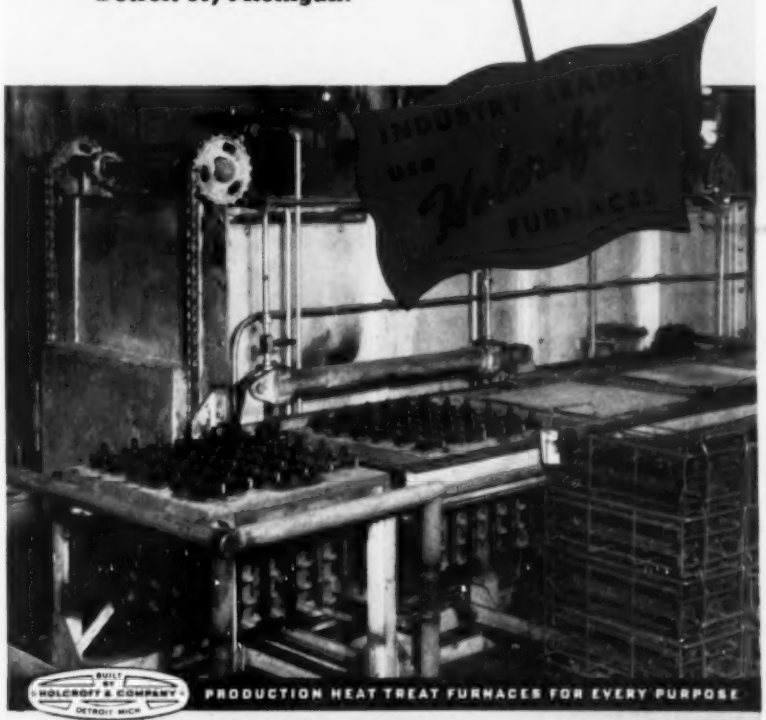

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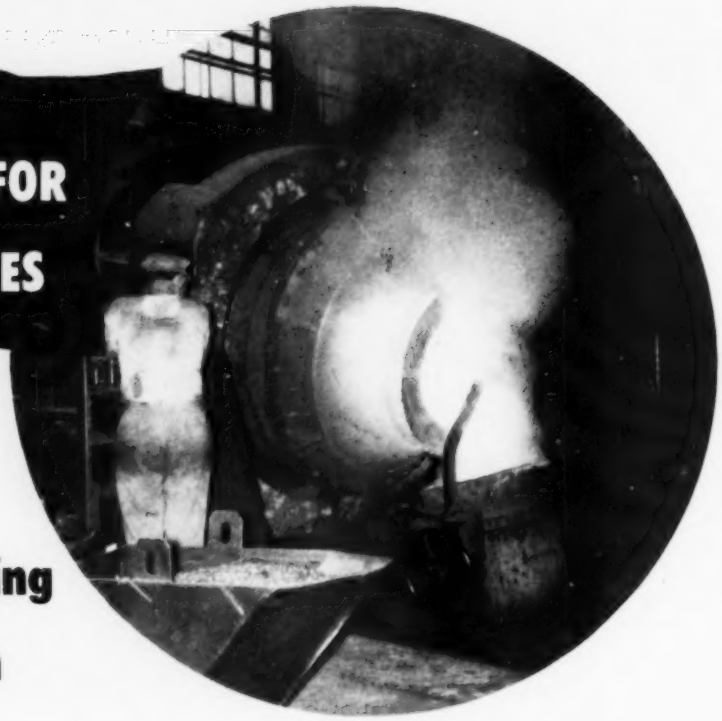
Tasil LININGS FOR ROTARY FURNACES

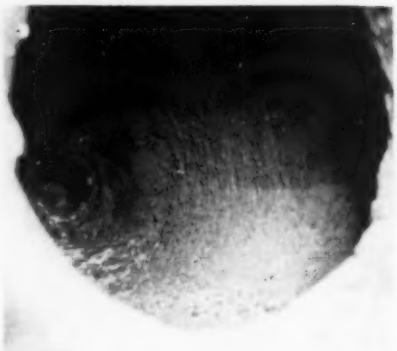


- **Last Longer**
- **Produce Less Slag**
- **Require Less Patching**
- **Increase Production**

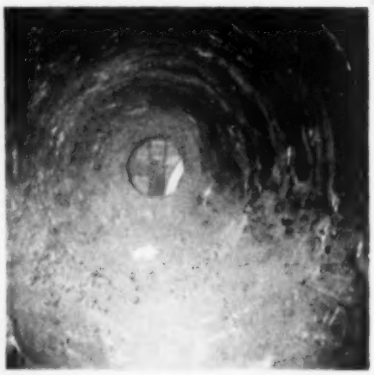
The following performance report is based on the experience of a large producer of centrifugal castings, operating rotary furnaces lined with Taylor Sillimanite (TASIL) super-refractories. This modern foundry manufactures bushings, rolls, pump rotors, etc., for textile and pulp and paper industries. Furnaces are also used for the recovery of scrap, chips and turnings, cast into ingots. (See photographs at right.)

•

If your foundry is melting similar alloys in rotary furnaces, it will pay you to investigate this proven TASIL application. For detailed information, call your nearest Taylor representative or write direct.



Photograph shows the TASIL brick and shape lining of a 2-ton rotary furnace *after three years* of intermittent service. Over 1,000,000 lbs. of monel and copper-nickel alloys were melted in this lining. There is no evidence of wear or joint erosion. The original 32" inside diameter has been maintained.



This photograph shows the condition of a *fireclay brick lining* after 15 months service in a 5-ton rotary furnace operated by the same manufacturer, in the same foundry, as furnace in photo above. Approx. 730,000 lbs. of low melting point alloys were melted. Service of this furnace was less severe, as very few copper-nickel heats were melted. Note extreme slagging. Lining has lost 2" to 3" in vulnerable areas.

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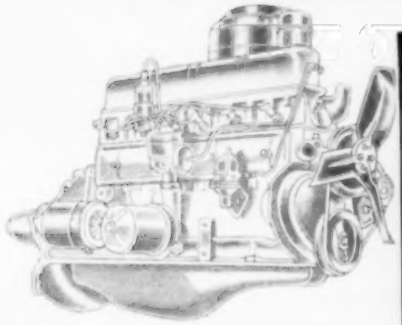

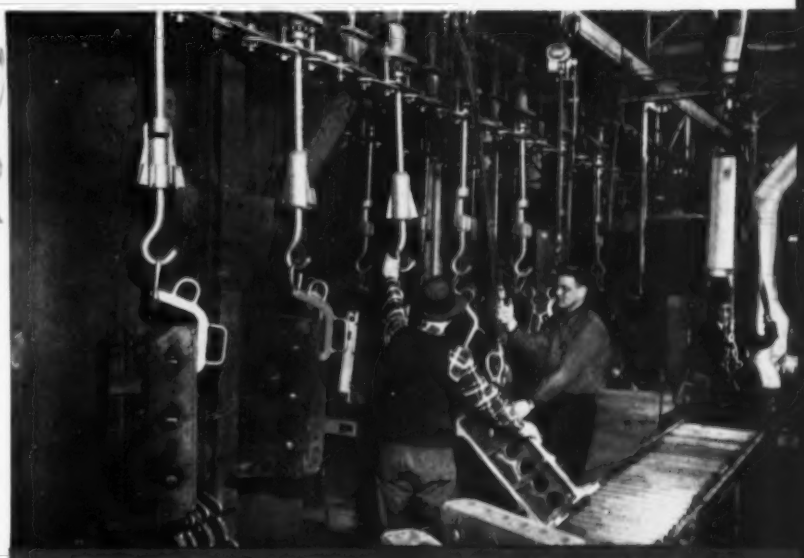

Pangborn Machine #2 cleaning cylinder blocks. Worker at right transfers castings from grinder to station where two workers in center foreground load them on conveyor hooks for cleaning.

Clean 80 tons of castings an hour at the Ford Cleveland Foundry

At no point are Ford's quality requirements more exacting than at its new Cleveland foundry—production show-place of the Ford Motor Company. That's why it's important that Ford chose Pangborn Special ROTOBLAST® Cleaning Machines to handle the major part of this foundry's blast cleaning. The total output of these five monorail machines will be 80 tons of castings cleaned per hour.

Ford picked Pangborn because parts must be cleaned *perfectly*, even beyond the demands of adequate performance—and *quickly*, to keep pace with other production processes, to keep costs in line! Pangborn can give *you* the same better, faster, cheaper performance. If you have *any* blast cleaning problem, write today for Bulletin 214. Write to: PANGBORN CORPORATION, 1800 Pangborn Boulevard, Hagerstown, Maryland.

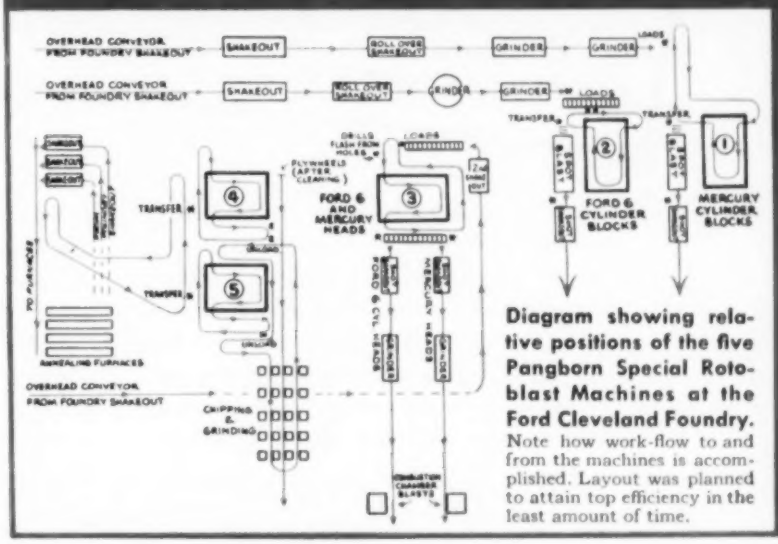

Diagram showing relative positions of the five Pangborn Special Rotoblast Machines at the Ford Cleveland Foundry. Note how work-flow to and from the machines is accomplished. Layout was planned to attain top efficiency in the least amount of time.

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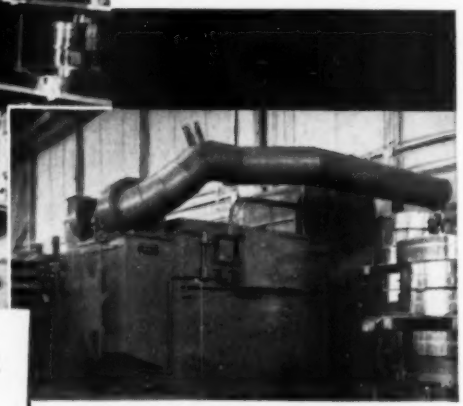
ANOTHER DRY REPORT ON ANOTHER WET YEAR ON KENILWORTH STEEL'S STORAGE OF FINE STEELS

Steel stored in this DRY stock-room—tempered spring steel, feeler gauge and shim steel—needs no grease coating to protect it.



This Lectrodryer* DRYs the air fed to this stockroom at The Kenilworth Steel Company, Kenilworth, New Jersey.

"... the wet summer we had here again verified the value of Lectrodryer equipment. We wish to add, however, that drying is definitely a wintertime advantage, too."

Sizable savings in time and money, credited to this Lectrodryer installation a year ago, have been confirmed during another WET year. Because moisture is taken out of the air which surrounds the fine steels kept here, prompt shipment can be made right from stock; no time-consuming delay while the steel is degreased.

You buyers of steel, who visit The Kenilworth Steel Company's plant, should ask to see this stock room. Perhaps you can use a Lectrodryer to equal advantage, safeguarding materials in stock or being processed against attack by moisture.

Bulletin 222, "Because Moisture Isn't Pink", tells you how others are using Lectrodryers for DRYing air, gases and organic liquids. For a free copy, write Pittsburgh Lectrodryer Corporation, 317 32nd Street, Pittsburgh 30, Pennsylvania.

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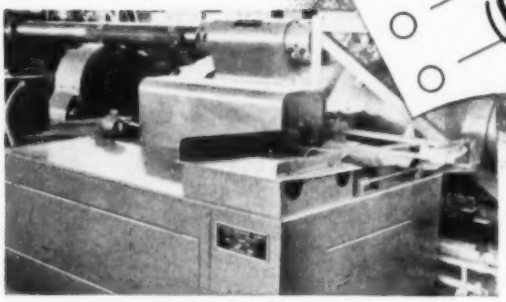
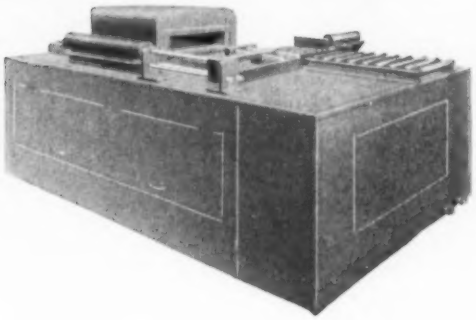
SOME Practical Information about Low-Frequency (60-cycle) Induction Heating . . .





IS IT NEW? Low-frequency induction heat, utilizing one of the commercial frequencies (normally 60 cycles), is one of the oldest forms of induction heat . . . but, the development of equipment to heat non-ferrous billets by 60-cycle induction is relatively new. Magnethermic pioneered these induction heaters five years ago.

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HOW USED? 60-cycle induction heating provides a highly efficient method for heating metals, both ferrous and non-ferrous, for forging, extrusion or annealing. Low-frequency heating has its limitation primarily in the heating of small pieces. For instance, steel bars 4" in diameter and larger can effectively be heated to forging temperature. With aluminum, this figure is reduced to 1⅛" minimum and with brass to 3". 60-cycle induction heating provides a rapid, highly efficient, clean and economical method for heating metals.

SIZE RANGE. The size range embraces heaters for heating 4-oz. aluminum forge slugs to units for heating billets 32" in diameter and weighing over 6,000 pounds.

NEW USES. New uses for 60-cycle heating are constantly being explored. Steel, titanium, zirconium and many other metals present a challenge to the induction heating manufacturer that can best be answered in the laboratory. Our development department is constantly working on these problems and many others.

We invite your inquiry on any special heating problem that you may have.

60-CYCLE

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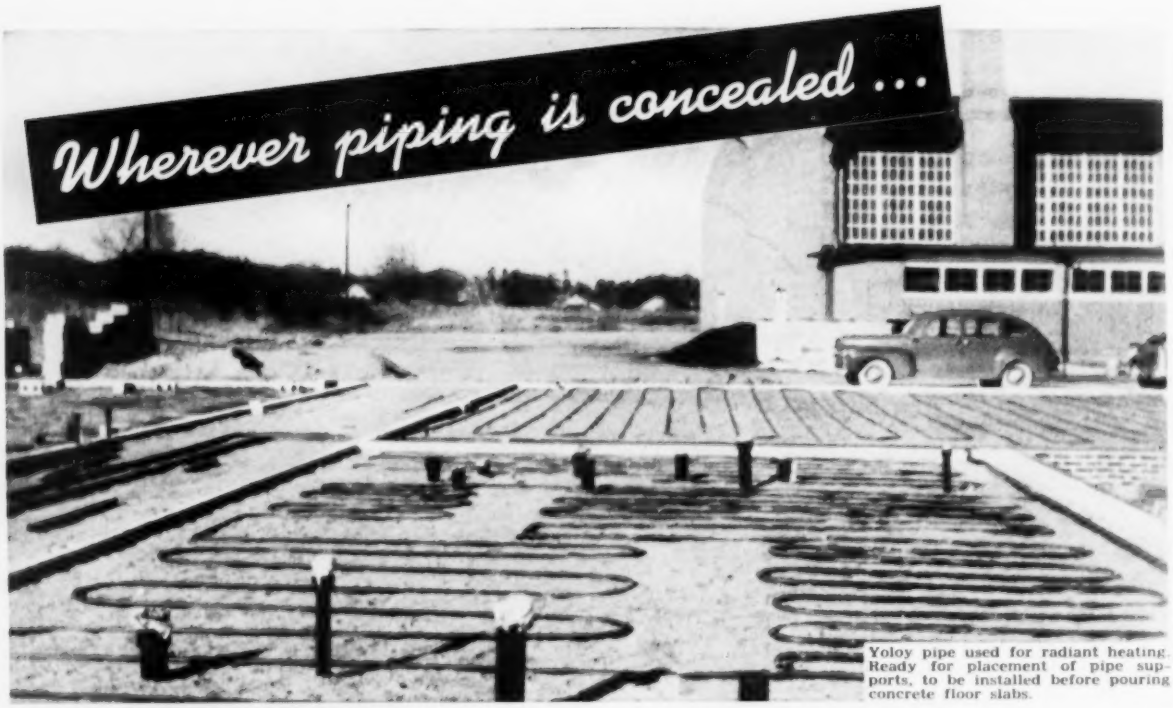
3990 SIMON ROAD YOUNGSTOWN 7, OHIO

INDUCTION HEATING



Yoloy pipe used for radiant heating. Ready for placement of pipe supports, to be installed before pouring concrete floor slabs.

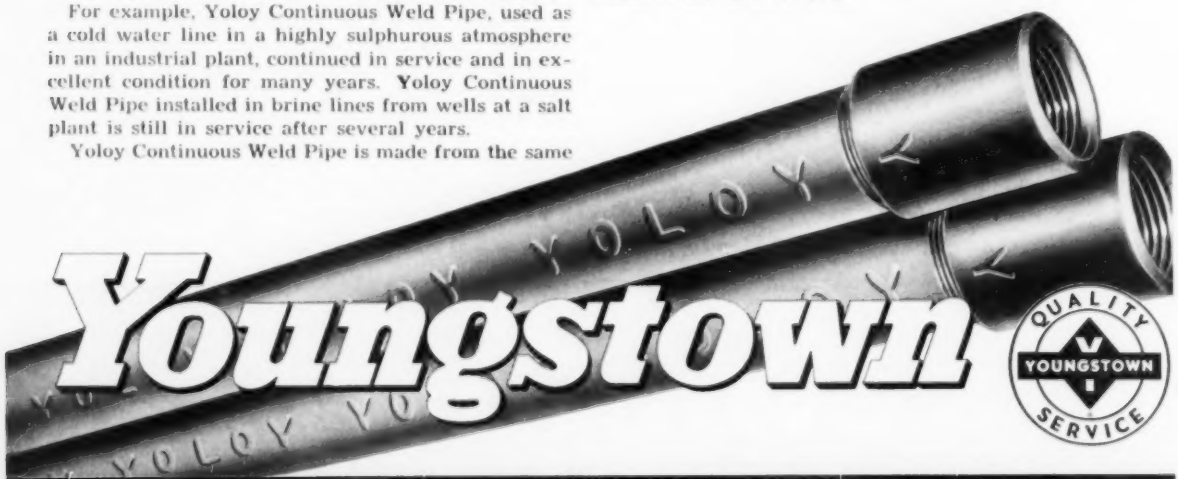
use YOLOY continuous weld pipe

Yoloy Continuous Weld Pipe offers distinct advantages for radiant heating and snow removal. Its use is recommended whenever piping is concealed—in industrial plants, commercial buildings, hospitals, schools and residences.

In standard tests Yoloy steel has demonstrated that its resistance to atmospheric corrosion is four to six times greater than that of regular steels. In actual installations Yoloy Pipe has demonstrated that it has a high resistance to many other corrosive conditions.

For example, Yoloy Continuous Weld Pipe, used as a cold water line in a highly sulphurous atmosphere in an industrial plant, continued in service and in excellent condition for many years. Yoloy Continuous Weld Pipe installed in brine lines from wells at a salt plant is still in service after several years.

Yoloy Continuous Weld Pipe is made from the same nickel-copper steel composition that has proved so successful in service in the oil, mining, railroad, chemical, trucking and other industries where resistance to corrosion and abrasion is of prime importance. This pipe is easy to thread and fabricate with standard pipe tools. It can be electric or gas welded readily. It has high strength and high resistance to abrasion, shock and vibration fatigue. For further information, write or phone the Youngstown District Sales Office nearest you.



THE YOUNGSTOWN SHEET AND TUBE COMPANY

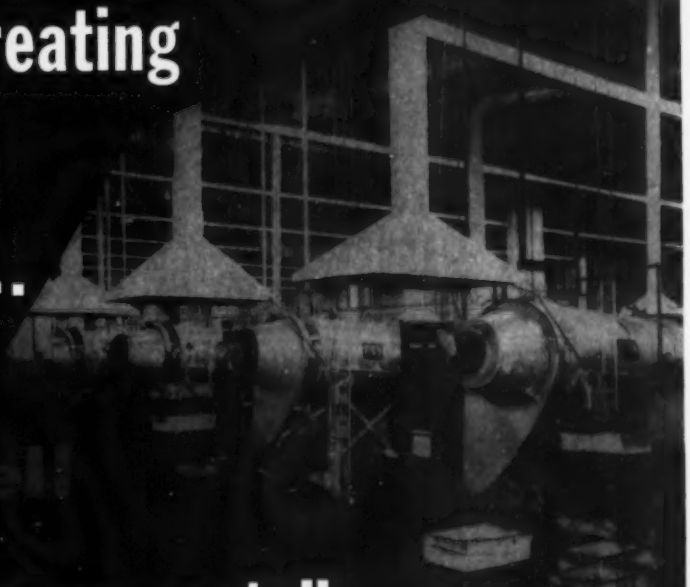
Manufacturers of Carbon, Alloy and Yoloy Steel

General Offices — Youngstown 1, Ohio

Export Office-500 Fifth Avenue, New York

COLD FINISHED CARBON AND ALLOY BARS - ELECTROLYTIC TIN PLATE - COKE TIN PLATE - WIRE - PIPE AND TUBULAR PRODUCTS - CONDUIT - RODS - SHEETS - PLATES - BARS - RAILROAD TRACK SPIKES.

When heat-treating spells "punishment"...



"lowest heat-hour costs"

When cold loading, intermittent operation, high temperature, and fast quenching are the order of the day, furnace parts and fixtures made from Driver-Harris alloys stay on the job—give top-level performance however punishing the heat-treating cycle.

Take a typical example: American Screw Company, of Willimantic, Connecticut says: "We employ a bank of seven American Gas Furnace Company's rotary carburizers, equipped with D-H Nichrome retorts, for case-hardening and heat-treating sheet metal and aircraft screws. Work is loaded cold. Operating temperature is 1650°F. The carburizers are also used occasionally at 1850°F. for hardening of stainless steel. Since we do not "baby" these machines by preheating loads, we consider we have very good success with the Nichrome retorts, each of which delivers, on the average, over 9,000 hours of trouble-free service."

And looking at the record generally, there are innumerable instances to show that Nichrome furnace components are remarkably efficient, economical, and long-lived. Large Nichrome retorts, handling 1800-lbs. of work, have served up to 24,000 hours apiece in rotary gas carburizers at temperatures of 1600°F. to 1650°F.; and Nichrome retorts in vertical carburizing furnaces, operating at 1650°F., have given as much as 36,000 hours of highly satisfactory usage.

It all goes to prove that Nichrome* and other specially developed D-H cast alloys, such as Chromax* and Cimet*, are unexcelled for conventional applications and indispensable for economical operation when heat-treating conditions are unusually tough.

Send us your specifications. Our engineers will be glad to make recommendations based on your particular requirements.

Nichrome, Chromax and Cimet are produced only by

Driver-Harris Company

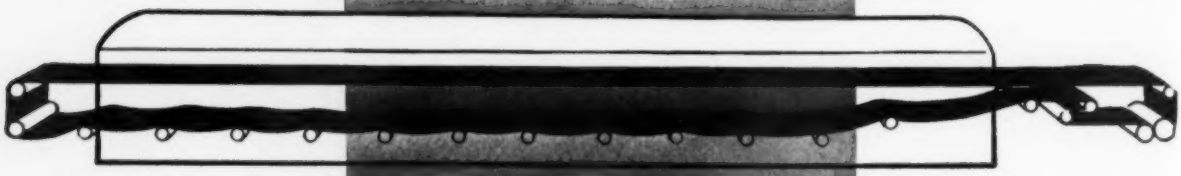
HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

*T. M. REG. U. S. PAT. OFF.

MAKERS OF WORLD-FAMOUS NICHROME AND OVER 80 ALLOYS FOR THE ELECTRICAL, ELECTRONIC, AND HEAT-TREATING FIELDS

hitch your HEAT to a



WISSCO STEEL PROCESSING BELT

■ If your product requires heat processing you can turn it out faster and more economically in continuous-line production with a Wissco Steel Processing Belt.

Wissco Belts give you the advantage of extra durability and heat resistance of chrome nickel alloys...the adaptability and low thermal values of open mesh construction...plus the economy of continuous operation.

To order, write or phone our nearest district sales office.

THE COLORADO FUEL AND IRON CORPORATION—Denver, Colorado

THE CALIFORNIA WIRE CLOTH CORPORATION—Oakland, California

WICKWIRE SPENCER STEEL DIVISION—Atlanta • Boston • Buffalo • Chicago • Detroit • New York • Philadelphia

1197

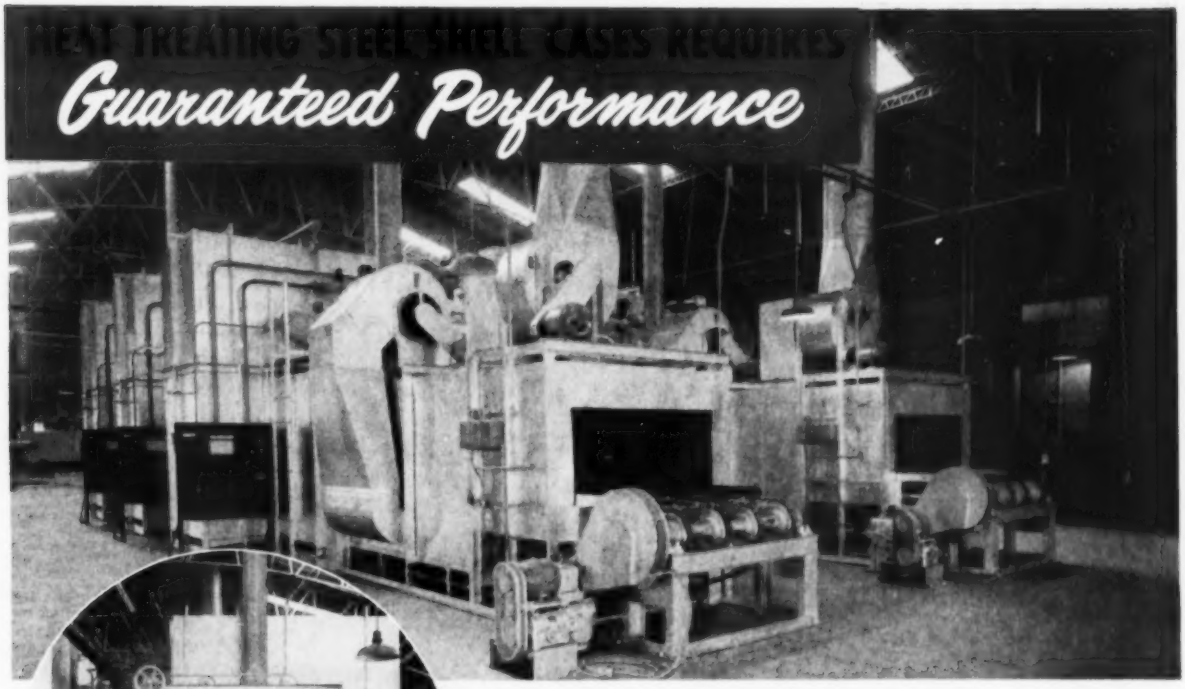
WISSCO BELTS

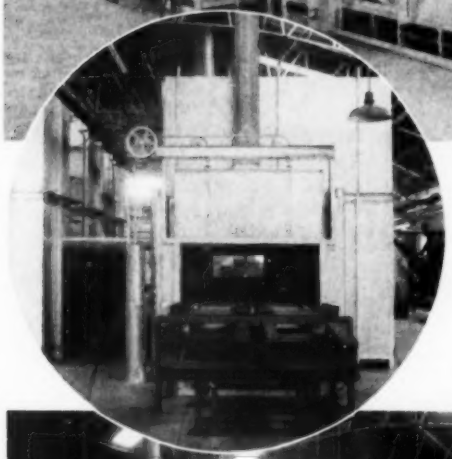
PRODUCT OF WICKWIRE SPENCER STEEL DIVISION
THE COLORADO FUEL AND IRON CORPORATION

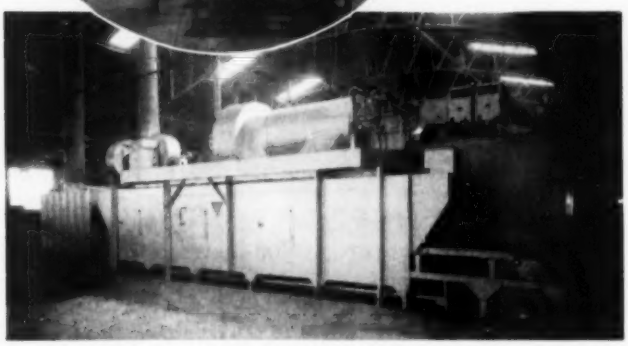
CFI

HEAT TREATING STEEL SHELL CASES REQUIRES

Guaranteed Performance







Get New Speed, Greater Economy, Higher Quality with

DESPATCH FURNACES

Modern DESPATCH Furnaces are engineered to meet specific production problems. That is why in plant after plant where DESPATCH Furnaces are on the job, production records show faster output and higher product quality at lower operating and maintenance costs.

You can count on DESPATCH Furnaces on your production line to give guaranteed performance. They are specially designed to give you faster heat transfer and uniform heat control to every part of the work chamber.

Write • Phone • Wire DESPATCH TODAY!

Blueprints of layouts for various sized shell cases are available upon request. We assure you prompt delivery of any furnace you need. Write, phone or wire for blueprints and quotations today, to Dept. P.

A TRIO PROVIDING SMOOTH, UNINTERRUPTED PERFORMANCE

These pictures illustrate one of many DESPATCH production lines in operation for the heat treating of steel shell cases. Top photo shows two DESPATCH annealing furnaces working side by side. In the circle is a close-up of the entrance end to one of them. Bottom photo shows a DESPATCH stress relieving furnace. All phases of the operations are under rigid control and provide smooth, uninterrupted performance with absolute assurance of proper heat treatment in every load.

DESPATCH OVEN COMPANY

Minneapolis Office:
619 S. E. 8th St.

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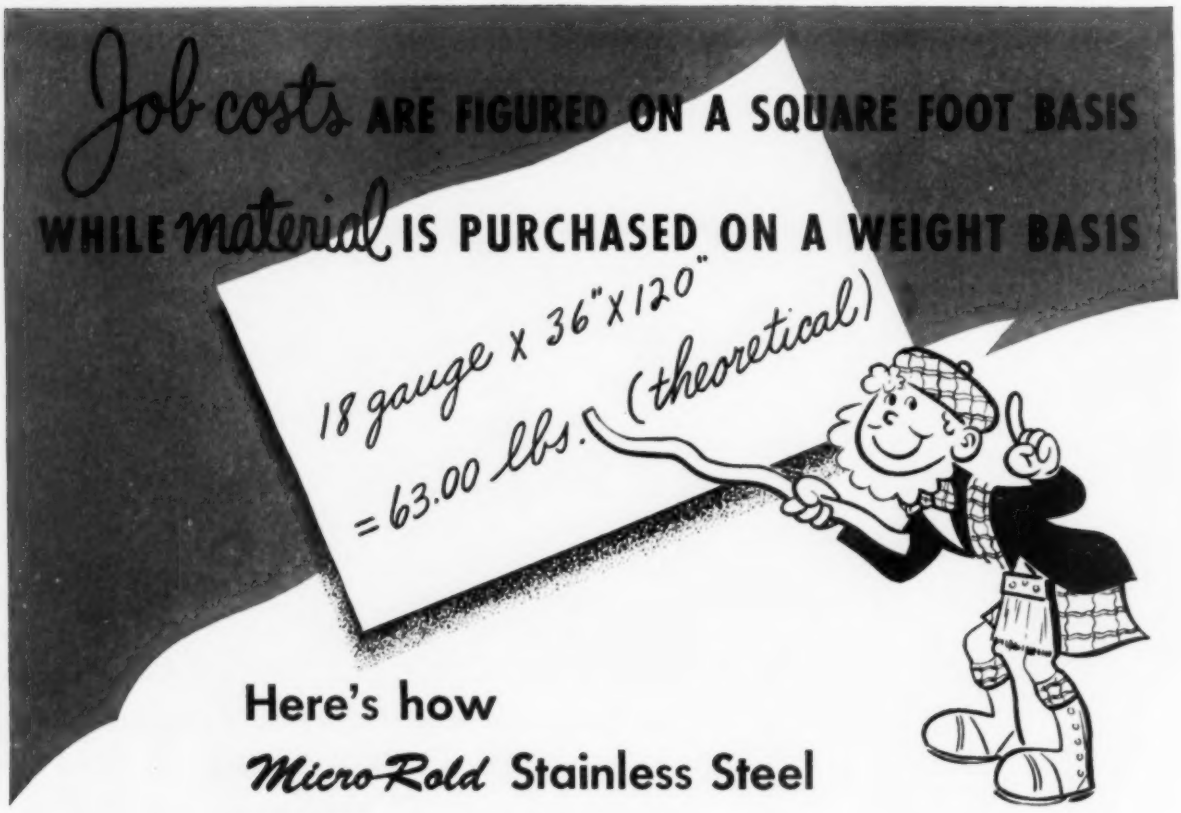
4554 N. Broadway

Sales Offices in all principal cities

PIONEERS IN ENGINEERING HEAT APPLICATIONS FOR INDUSTRY

Job costs ARE FIGURED ON A SQUARE FOOT BASIS

WHILE material IS PURCHASED ON A WEIGHT BASIS



Here's how *MicroRold* Stainless Steel SAVES you money

In the use of stainless steel, the selection of gauge number is usually determined by the minimum permissible thickness having sufficient strength to meet the requirements of the application. When you receive material on the heavy side of the gauge you are paying a premium for stainless surface area.

When sheets are ordered by gauge number, the permissible A. I. S. I. variation in thickness is plus or minus 10%. Thus, if you order 18 gauge, you may receive sheets .052" thick, when a thickness of .0475" would suit your purpose. Using a standard 18 gauge 36" x 120" sheet as an example, the theoretical weight is 63.00 pounds, but this weight could permissibly vary between 59.22 pounds and 65.52 pounds. Each .001" of thickness adds 1.26 pounds per sheet.

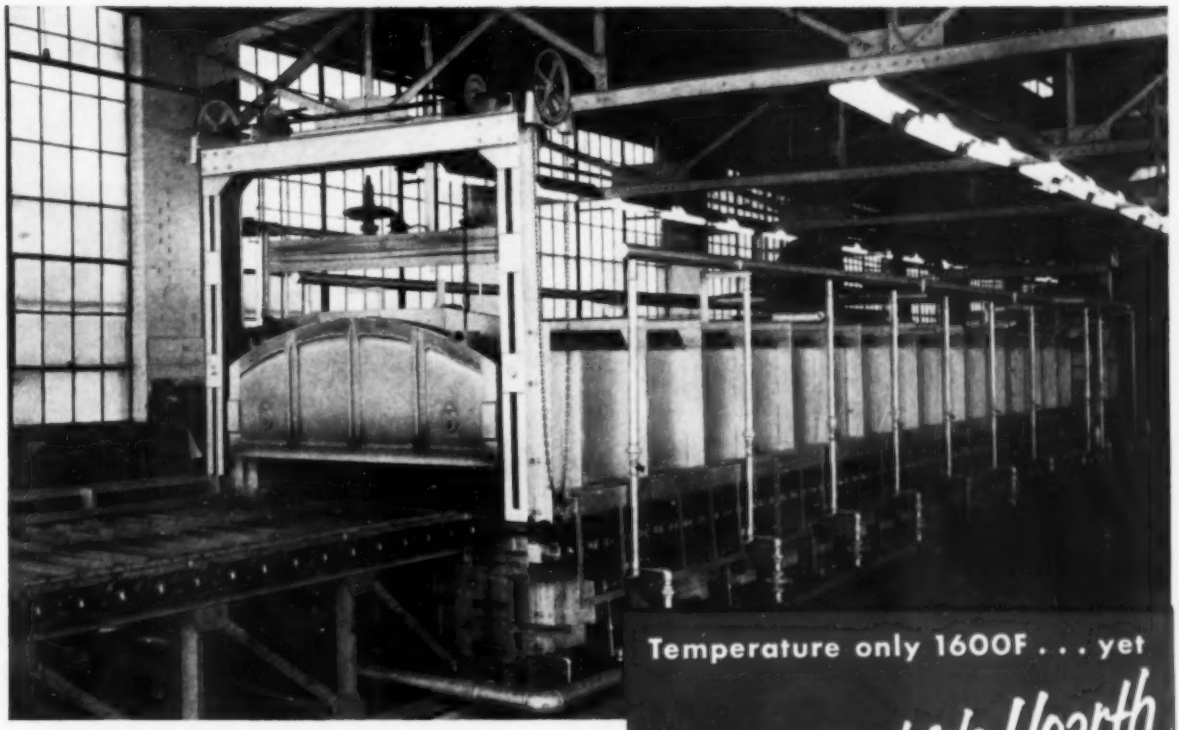
MicroRold sheets may be ordered by gauge number and you can specify they be rolled on the light side of the gauge range. This is true because the equipment is such that more accurate control of thickness is possible.

If you are not a user of MicroRold sheet it will pay you to get the full details. Your steel warehouse distributor will gladly tell you the MicroRold story.

Washington Steel

CORPORATION

WASHINGTON, PENNSYLVANIA



These armor-plate hardening furnaces, built by The Drever Co. of Philadelphia, Pa., range from 40′ to 60′ long, by about 7′ wide. There are seven furnaces like this operating at various plants. Each is equipped with a CARBOFRAX hearth. Average hearth life ranges from 18 to 36 months, depending on tonnage handled.

Temperature only 1600F . . . yet

Silicon Carbide Hearth Proves Best

Saves fuel . . . Heats more rapidly, and uniformly

This is a continuous roller-hearth hardening furnace, used for treating armor plates (up to 6′ wide, up to 20′ long, and in varying thicknesses up to 3″). It is under-fired with oil and/or gas to a chamber temperature of 1600 F. The work is carried on metal rollers over a hearth made of CARBOFRAX silicon carbide tile.

It is interesting that CARBOFRAX refractories were selected even though two of the outstanding properties of this material — its resistance to high temperatures and abrasion — are not brought into play. The reason for their selection, of course, lies in the tremendously rapid thermal conductivity of CARBOFRAX refractories. They conduct heat 11 to 12 times faster than fireclay. The result is a far more efficient furnace; one that heats uniformly, and can be closely controlled. It also takes less fuel — and the refractories are exceptionally long lasting.

This application brings home another point — i.e. not all silicon carbide refractories are the same. Other brands have been tried in similar furnaces, but due to premature oxidation, could not approach the life of these CARBOFRAX hearths.

Why Not Check Up? Chances are, your furnaces can be impressively improved by super refractories by CARBORUNDUM. Write or phone us today. Product data promptly furnished. Address: Dept. C-43, Refractories Division, The Carborundum Company, Perth Amboy, New Jersey.

CARBORUNDUM

Trade Mark

"CARBORUNDUM" AND "CARBOFRAX" ARE REGISTERED TRADEMARKS OF THE CARBORUNDUM CO. — WORLD'S LARGEST MANUFACTURER OF SUPER REFRACTORIES

Cleaning Specialists

Anyone can do a cleaning job that *looks* good but a Northwest Chemical cleaning operation brings 'em REALLY CLEAN—gets at those tough-to-crack, invisible trouble makers that turn up on final inspection as costly rejects.

We at Northwest take a personal interest in your cleaning problems. Our thoroughly experienced staff of chemical technicians will be pleased to help you solve your cleaning difficulties. Their broad experience may save you time and money with a simple formula adjustment or a complete new processing to fit your exact requirements.

No job is too small for our attention nor too large for our abilities.

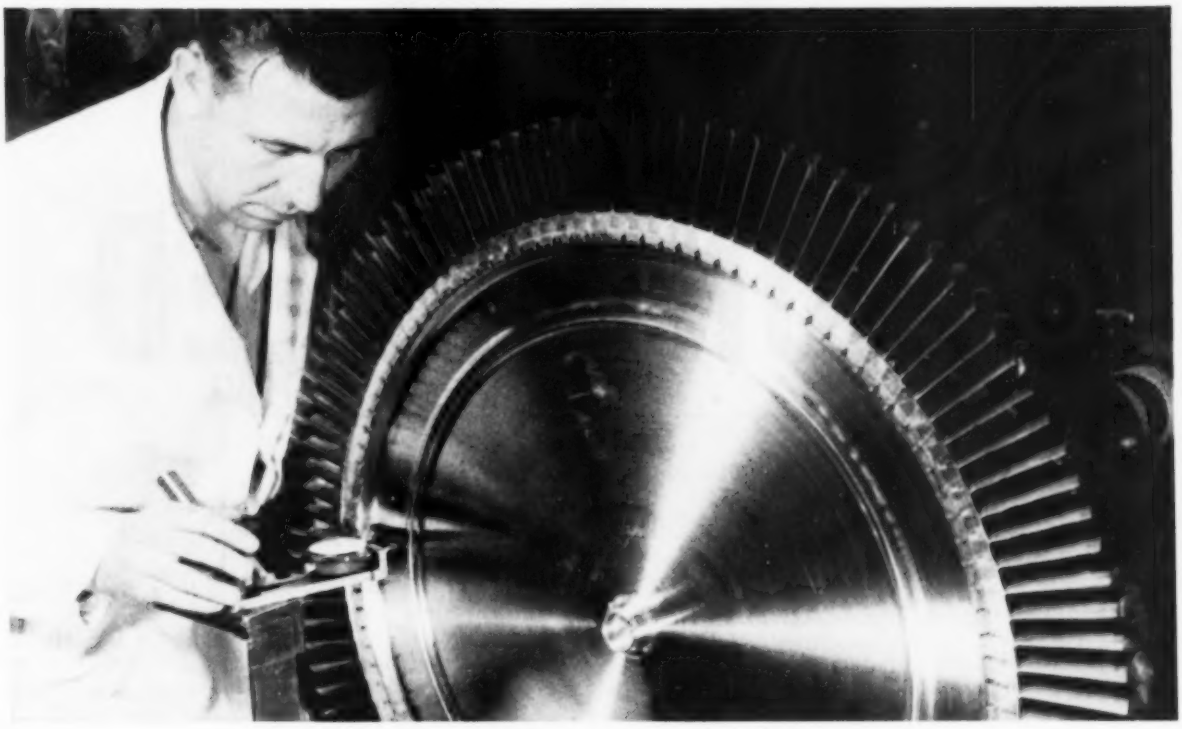
Got a problem? Let our cleaning experts help you!

NORTHWEST CHEMICAL CO.

9310 ROSELAWN DETROIT 4, MICH.

pioneers in pH cleaning control *serving you since '32*

A.V. ROE CANADA LTD. specifies "16-25-6" for rotor wheels in new Orenda jet engine



FROM the first designs to volume production, "16-25-6" was the alloy selected for rotor wheels in the new Orenda jet engine. A. V. Roe Canada Limited says, "No other alloys were considered during the development, since this particular alloy had become identified by and large as *the* successful specification . . . ".

Acceptance like this has made "16-25-6" the most popular super-alloy steel for jet engine rotor wheels. It was first developed by the Timken Company during World War II and since it was the *one* suitable steel that could be produced commercially for jet engine rotor wheels, it helped make jet propulsion practical.

Today, more "16-25-6" goes into solid and composite jet engine rotor wheels than all other super-alloy steels combined! That's because "16-25-6" has the *best* combination of the three top requirements for jet engine rotor wheels: 1) It has good high temperature properties. Operating at temperatures up to 1500°F., it retains high creep and stress rupture strength. And it has excellent resistance to scale and corrosion. 2) It is relatively low in strategic alloys. "16-25-6" uses none of the highly strategic alloys, contains no cobalt or columbium. 3) It has good machinability.

Make use of the Timken Company's wide experience in high temperature steels. We'll help you adapt "16-25-6" to your purposes—or help you pick other alloy steels suited to your needs. Write The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING

TIN DECONTROLLED

NOW Tin May Be Purchased

By Any User—in Any Quantity—for Any Purpose

For the first time since early in 1951, tin is free of U.S. Government controls as to use, stocks and shipment. On February 6 the National Production Authority removed all restrictions on this vital metal.

The only Government requirement remaining is that tin consumers and dealers submit monthly reports on their stocks, receipts, shipments and consumption.

This new order means that now tin may be purchased by *any* user—in *any* quantity—for *any* purpose.

It means that one of the world's most important metals is again freely available to American industry.

The NPA announcement says in part:

> The supply of tin contracted for and otherwise obtainable in world markets for use in this country now is sufficient to balance against demands, both Government and civilian.

TIN IS VITAL—The tin producers of Malaya, principal source of the world's supply, welcome removal of controls that have misled American industry into a wasteful and costly search for substitutes for tin.

Tin is vital to the security of the United States, Malaya and the Free World.

Tin is vital to the economy of the United States, Malaya and the Free World.

Just as the United States and Malaya are allies in defense of the Free World, so are they partners in tin. And by gaining the offensive in its war against Communist guerrillas, Malaya has materially strengthened its position as the world's most important supplier of tin for the needs of the United States.

. . .

To supply accurate information about tin and to report on new developments, we publish a monthly newsletter. Write now for the current issue of "Tin News" with important supplement on the official NPA announcement.

THE MALAYAN TIN BUREAU

Department 345

1028 Connecticut Avenue **Washington 6, D.C.**

There is No Real Substitute for Tin

With INCONEL heat-treating fixtures...

you take the dents out of accidents!

After a furnace pile-up in one plant recently, the fixtures looked pretty hopeless.

Some were bent and broken, like the one shown at the top. Others were flattened almost beyond recognition.

Ordinarily, scrapping the lot would be a logical thing to do. Fixtures don't last forever, and these had been used six months in an infiltration process involving a hydrogen atmosphere and 2000° temperatures.

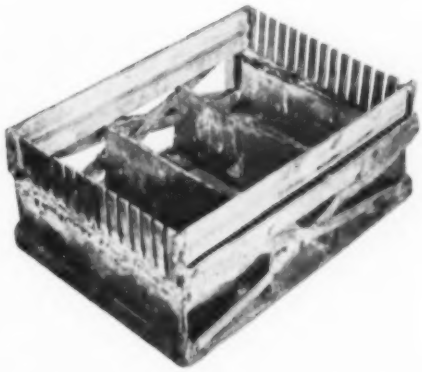
But these were Inconel® fixtures! Despite the severe service they had seen – and the accident that had knocked them flat – they could be repaired. *The metal itself showed no sign of deterioration.*

So back the fixtures went to the ALLOY ENGINEERING COMPANY, of Berea, Ohio, who had designed and fabricated them. They had no difficulty in reconditioning them, and the fixtures are now back in service. The user says they are as good as new.

And the cost? Just 25% of the price of replacement fixtures!

With Inconel, stories of salvage operations like this are not unusual. And neither are remarkable service records. For Inconel is a tough, long-lasting metal that resists corrosion, embrittlement and destructive oxidation at temperatures up to 2200° F.

READY for the scrap pile?



NO! – Repaired and back to work!

In heat-treating service, Inconel fixtures have outlasted others by as much as ten times.

Look over your own heat-treating installations. You may find many places where Inconel can help make substantial long-range savings possible.

It is advisable to place equipment orders with your supplier well in advance of scheduled use. Distributors of Inco Nickel Alloys can supply you with the latest information on availabilities from warehouse and mill.

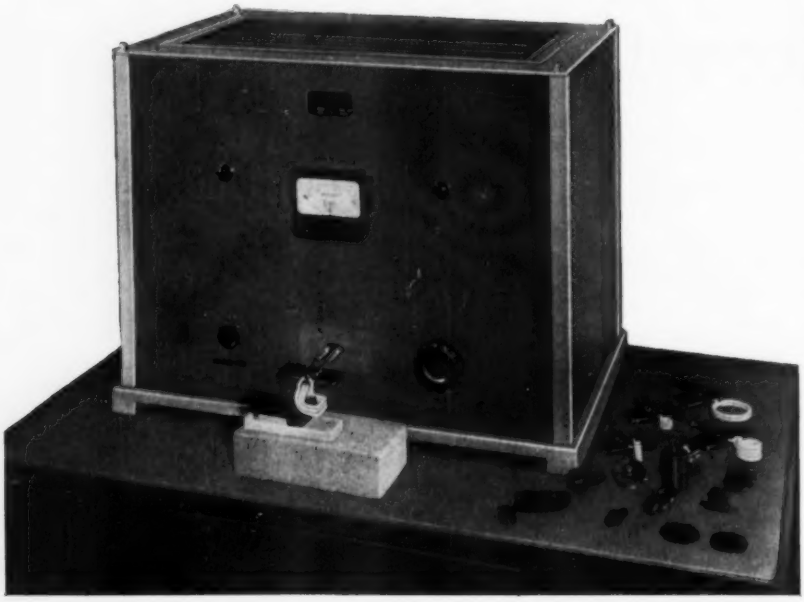
If you have a special problem, and would like the assistance of our High-Temperature Engineers, ask us to send you a copy of "The High-Temperature Work Sheet." This specially designed form makes it easy for you to describe your individual problem.

Inco Nickel Alloys

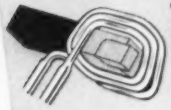
MONEL® • "R"® MONEL • "K"® MONEL • "KR"® MONEL
"S"® MONEL • NICKEL • LOW CARBON NICKEL • DURANICKEL®
INCONEL® • INCONEL "X"® • INCONEL "W"® • INCOLOY® • NIMONICS®

Lepel presents

A Low Cost PORTABLE HIGH FREQUENCY Induction HEATING UNIT

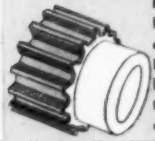


BRAZING



Permits widest choice of silver or copper brazing alloys from lowest to highest melting points. Ideal for brazing carbide tips.

HARDENING



Heat localized exactly where wanted at desired temperature. Ideal for gears, cams, bearing surfaces, cutting tools and other areas that are subject to wear.

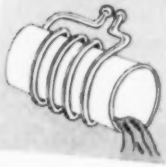
SOLDERING

Speedily and neatly performs intricate soldering applications with or without the use of pre-formed rings.

ANNEALING

Ideal for annealing, stress-relieving, normalizing or preheating selected areas.

MELTING



Readily melts quantities of ferrous and non-ferrous metals in either graphite or ceramic crucibles.

- **SMALL AND COMPACT** Conveniently operated on bench or table—no mounting necessary.
- **ECONOMICAL OPERATION** No special power installation required. Operates on 110 volts, 60 or 50 cycle line at unity power factor.
- **FULLY GUARANTEED** Guaranteed for continuous duty cycle and stated performance.

This versatile unit is priced so low that every shop may now take advantage of modern induction heating techniques to improve quality and to increase production. Its simplicity of operation eliminates the need for skilled personnel.

The Lepel Model 2 KW will meet the requirements of machine shops, toolrooms, research laboratories and educational institutions. It is especially suitable for hardening, brazing and soldering small parts of either ferrous or non-ferrous metals.

Complete unit with line connection and load coil.

$870.

f.o.b. factory

WILL HEAT TO 1500° F.

1/8"	steel	rod	1"	length	in	approx.	1 second
1/4"	"	"	"	"	"	"	3 seconds
1/2"	"	"	"	"	"	"	15 seconds
1"	"	"	"	"	"	"	60 seconds

Will melt 4 ounces of brass or steel in 4 minutes.
Equally well suited for heating of non-ferrous metals.

LEPEL HIGH FREQUENCY LABORATORIES, INC.
55th STREET and 37th AVENUE, WOODSIDE 77, NEW YORK CITY, N. Y.

All Lepel equipment is certified to comply with the requirements of the Federal Communications Commission. *Write for Lepel Catalog MP-12.*

SuVeneer®

STAINLESS

CLAD METAL

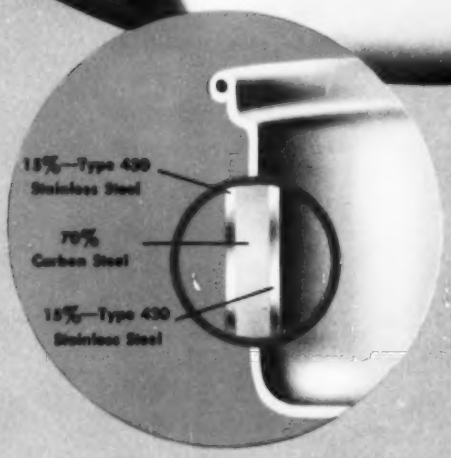
Wonderful for Cooking

★ Heats Easily

★ Heats Rapidly

★ Heats Evenly

★ Ideal for your fabrication methods



Fast, Even Heat Diffusion . . . No Hot Spots!

The word travels fast among consumers: get *stainless-clad* utensils now for better cooking . . . easy cleaning . . . stay-bright beauty! And the utensil maker says SuVENEER Stainless Clad Metal . . . for fabricating ease . . . for sales! Stainless both sides, mild steel in the center, furnished in coiled strip. Size, temper, finish to your specification. *Write.*

Superior Steel

CORPORATION

CARNEGIE, PENNSYLVANIA

NOW

You can afford a High Vacuum Furnace

This ONE

Versatile Unit lets you melt, pour, heat treat, degas

At last there is now available a single furnace that does away with the need to purchase equipment for each phase of your high-vacuum, high-temperature work. Because of its modest price, it will fall within the budget of most laboratories.

With this new furnace you can melt and solidify — melt and pour — add to the melt — stir — look into the hot zone — measure hot zone temperatures — introduce controlled atmospheres — degas — heat treat. It's a complete, versatile unit, capable of handling the widest variety of metallurgical research work. Write today.

FEATURES

- Ultimate vacuum of less than 5×10^{-5} mm. Hg.
- Working temperatures up to 2000° C.
- Temperature controllable within ± 5° C.
- Hot zone reaches temperature within two minutes.
- No refractories used in hot zone.
- 4" purifying type diffusion pump insures high capacity for out-gassing.
- Utilizes single turn low voltage resistance element of tungsten 2½" dia. x 5" high.
- Optional heating elements of larger size are available.
- Integral power supply for furnace.
- Manual temperature control. (Automatic control optional.)
- Thermocouple vacuum gage is standard equipment. Other gages are available.

INDUSTRIAL RESEARCH • PROCESS DEVELOPMENT
HIGH VACUUM ENGINEERING AND EQUIPMENT

METALLURGY • DEHYDRATION • DISTILLATION
COATING • APPLIED PHYSICS

National Research Corporation

Equipment Division

Seventy Memorial Drive, Cambridge, Massachusetts

REPUBLIC'S 3-DIMENSION METALLURGICAL SERVICE

helps you solve your steel problems

• You may be trying to finalize the choice of grades of alloy steel for a new product . . .

Or wondering if your present product is taking full advantage of the alloy steels you are now using . . .

Whether it's a new product or a well-established one, you may be able to make it stronger or better or to reduce production costs by calling in a Republic Field Metallurgist to discuss problems of alloy selection and production with your metallurgical and manufacturing men.

The Republic Field Metallurgist is backed-up in his recommendations to you by a Republic Mill Metallurgist and a Republic Laboratory Metallurgist. Together they offer a complete and extensive consulting service to steel users . . . Republic 3-Dimension Metallurgical Service. Available to you through your local Republic Steel sales office.

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N.Y.

. . . combines the extensive experience and coordinated abilities of Republic's *Field*, *Mill* and *Laboratory* Metallurgists with the knowledge and skills of your own engineers. It has helped guide users of Alloy Steels in countless industries to the correct steel and its most efficient usage. IT CAN DO THE SAME FOR YOU.

Republic ALLOY STEELS

REPUBLIC STEEL

Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

GLOBAR elements give you FOUR OUTSTANDING ADVANTAGES in electric furnace operation

TRADE MARK

1 **MORE HEAT...** *per unit area of hearth*

2 **WIDEST RANGE OF TEMPERATURES...** *up to 2750°F. accurately controlled*

3 **SIMPLICITY** *of furnace construction*

4 **LESS DOWNTIME...** *no need to cool or unload during replacement*

Get these exclusive advantages, plus the many other advantages of electric heat, by specifying furnaces equipped with GLOBAR silicon carbide heating elements by CARBORUNDUM. You'll find it pays—whether your brazing, heat treating, forging, sintering, or annealing.

GLOBAR heating elements provide heat that is clean, safe, quiet and uniform. They give you long, trouble-free service at low cost.

When you weigh all the advantages and savings in the operation of electric furnaces equipped with GLOBAR heating elements, you may find you can substantially reduce overall costs —even when electricity costs more than other fuels! For instance, you can often eliminate one or more of your present operations.

Get the full story today. Our engineers will be glad to assist you in selecting the most economical way of doing the job you want to do...without obligation. Write to Dept. MP 87-34.

GLOBAR Heating Elements by CARBORUNDUM

"Carborundum" and "Globar" are registered trademarks which indicate manufacture by The Carborundum Company, Niagara Falls, New York

Castings for the Connoisseur

If there were a gallery where casting works of art were displayed, there's no doubt that Sivyer castings would wear many a blue ribbon. Indeed, the most critical judging would reveal only casting perfection . . . unblemished finish . . . sharp corners . . . clean cored holes . . . absence of excess metal. Manufacturers who insist on the ultimate in steel castings know that the Sivyer ◇S◇ means less handling . . . lower machining time greater dependability . . . longer service life. Look for it.

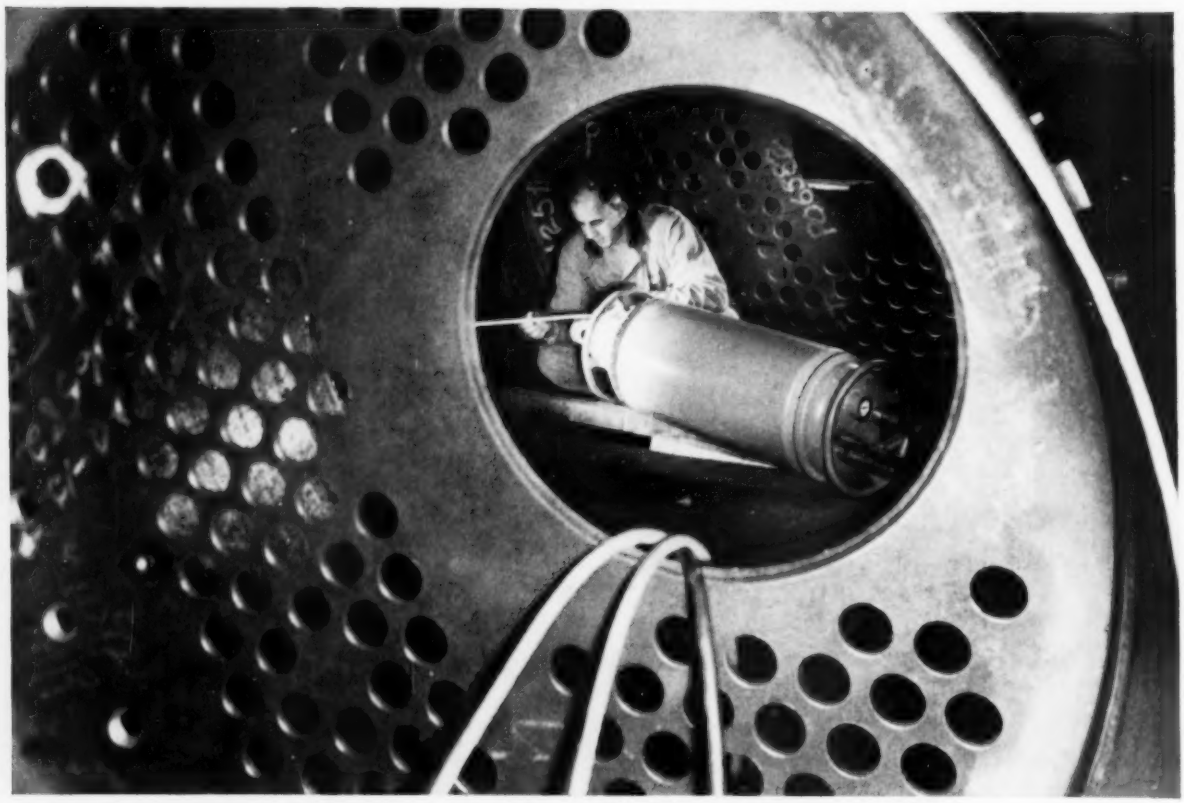
S

SIVYER

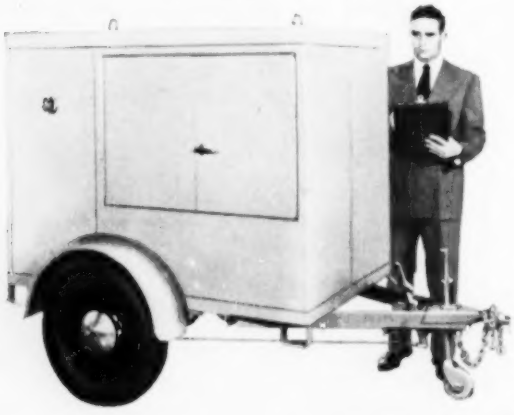
SPECIALISTS IN HIGH ALLOY AND SPECIFICATION STEEL CASTINGS

SIVYER STEEL CASTING COMPANY • MILWAUKEE ◇S◇ CHICAGO ◇S◇ MAIN OFFICE: 1675 SO. 43rd ST. • MILWAUKEE, WIS.

NOW — a *truly* portable industrial x-ray unit!
The General Electric RESOTRON 250



Compact, lightweight, 250,000-volt x-ray unit speeds inspection of large structures, saves many hours of set-up time



For radiographic examination of welds or castings in large structures, the new GE Resotron 250 offers unprecedented advantages. Completely housed in a cabinet only 4 x 6 x 4-foot high, which may be trailer-mounted, this unit can be set up anywhere in a few minutes by one or two men.

Small, lightweight tube head can be passed through a 15-inch diameter opening for interior inspection of large vessels. It's particularly adapted for ship hulls, pressure vessels, steam pipes. No cranes or elaborate rigging needed — can be manipulated manually.

Resotron 250 is the latest addition to the complete GE line of industrial x-ray apparatus . . . ranging up to 2,000,000-volt units and betatrons. It is actually a miniature of the famous General Electric million-volt Resotrons, with such time-proven features as resonant transformer, cascade tube and gas insulation.

Have you inspection problems the Resotron 250 might solve? See your local GE x-ray representative. Or write X-Ray Department, General Electric Company, Milwaukee 1, Wis., Rm. AS-4.

GENERAL ELECTRIC

first quality

DIE STEELS

for

HOT WORK

HOTFORM The original 5.00% chromium hot work steel—more widely used than any other type. Ideal for die casting dies, shell piercing tools, extrusion press tooling (for aluminum, magnesium, soft brass).

MARVEL High tungsten, tough, retains hardness at high heat. Popular for hot press and hot forging dies for brass and steel, refractory brass extrusion, hot swaging, hot shearing, etc.

and

HOTPRESS
FORGE DIE
SC SPECIAL
WW HOTWORK
RED CUT SUPERIOR
J-Temper

—write for details!

Vanadium-Alloys Die Steels for Hot Work are produced in grades covering the complete range of applications in this field. Each grade, distinguished by brand, embodies the specialized experience of almost half a century devoted *exclusively* to the production of fine tool and die steels. Whatever your hot work requirements, you'll find profitable fulfillment in our First Quality Die Steels. Our Research Department and metallurgically-trained sales representatives will gladly assist you in correct selection. *Let us send you our booklet on Die Steels for Hot Work.*

Vanadium-Alloys
STEEL COMPANY
LATROBE, PA.
COLONIAL STEEL DIVISION • ANCHOR DRAWN STEEL COMPANY

UNLESS YOU'RE WELDING IN *ARID ARIZONA*

you need... **BLUEWELD**

Aridair

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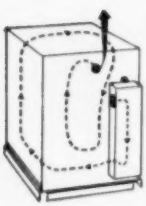
Moisture Content
STABILIZER

LOW HYDROGEN and STAINLESS STEEL ELECTRODE STABILIZER

Specifically designed and engineered to maintain correct moisture content.



EXCLUSIVELY ARIDAIR

- *Chemically dried air*
- *Shelf circulation*
- *Electrically heated*
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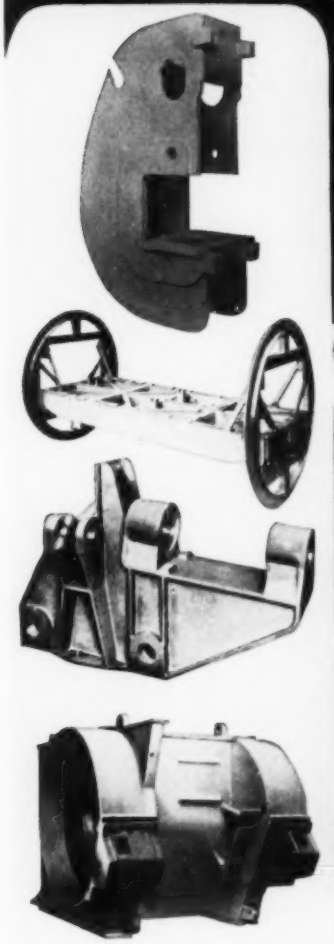
- *Recessed shelving*
- *Rigid construction*
- *Multiple unit stacking*

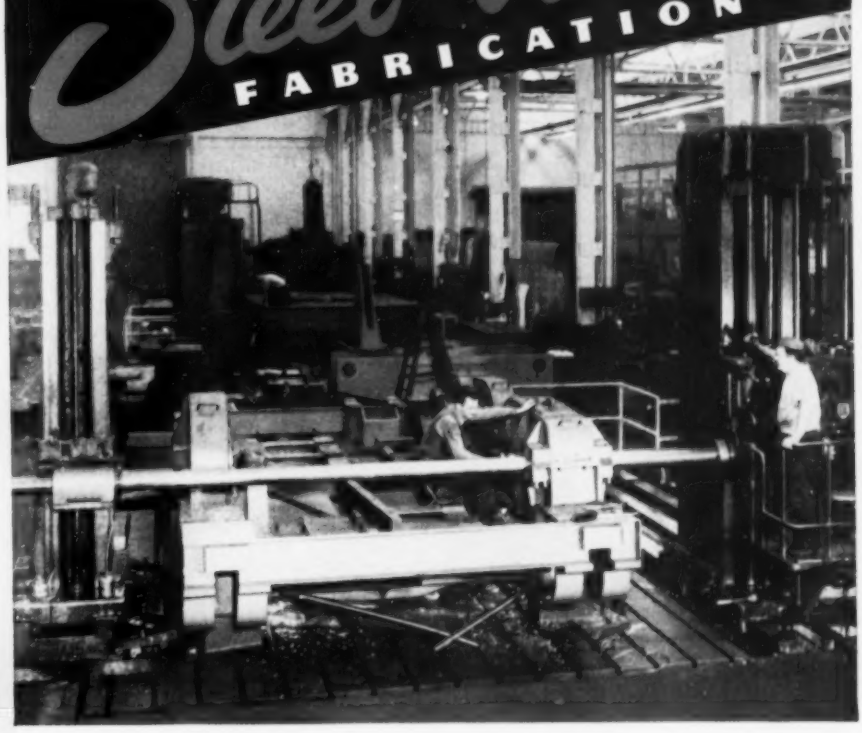
Write for details

Fred C. Archer, Inc.

MANUFACTURER
MILWAUKEE 3, WISCONSIN

Steel-Weld FABRICATION





Use WELDED STEEL for Greater Strength with Less Weight!

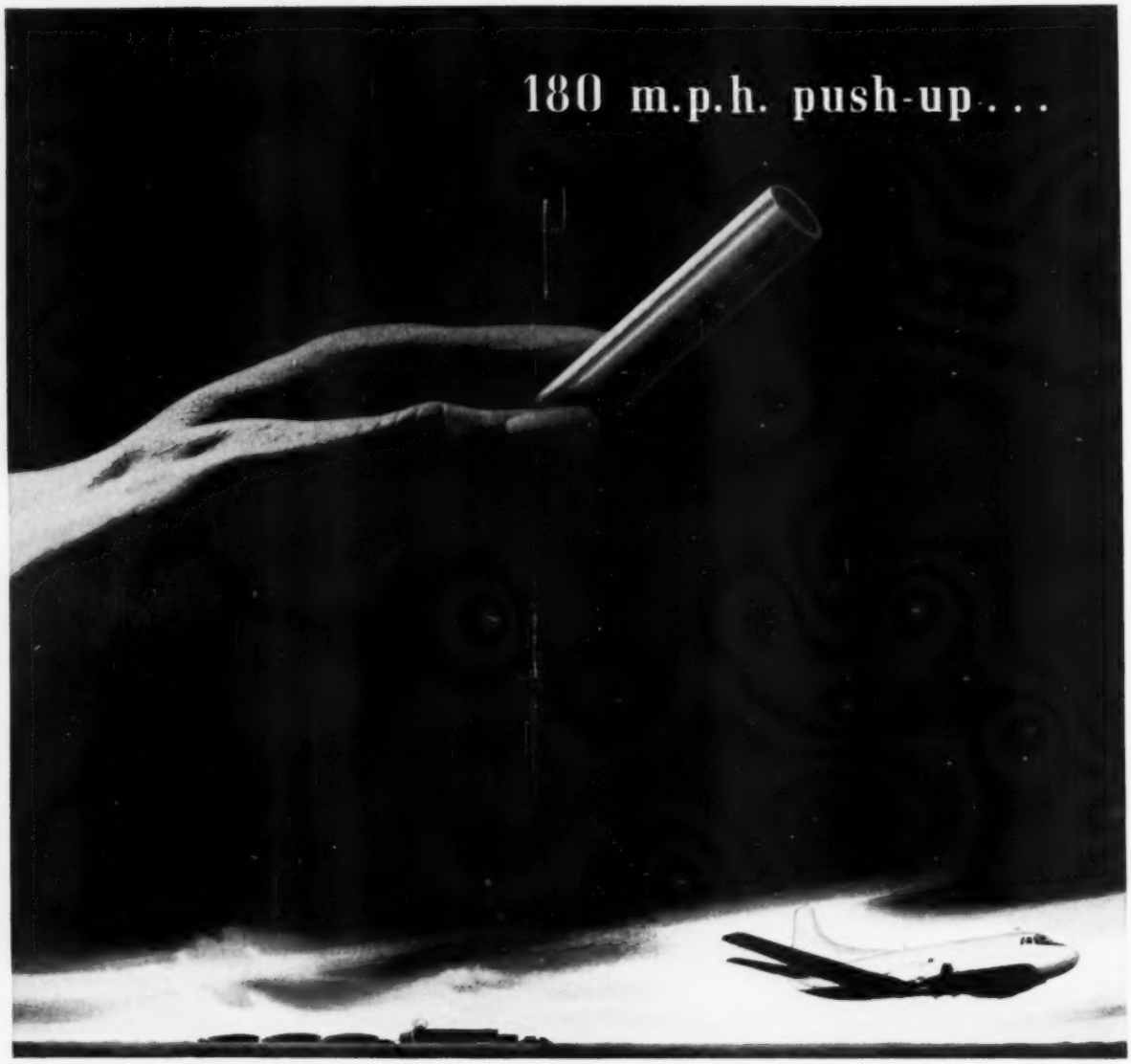
In the illustration above you see a portion of the Mahon machine shop where welded steel parts and assemblies of various sizes and weights are machined to specification for many industries throughout the country. Facilities are available right in the Mahon plant to do the complete job from the drawing board to finished machining ready for assembly. If you have parts or assemblies that can be redesigned and produced to better advantage through Steel-Weld Fabrication, or, if you are faced with a production problem involving large heavy pieces in which pattern costs are a consideration, you can turn to Mahon with complete confidence. You will find in the Mahon organization a unique source with complete, modern fabricating, machining and handling equipment to cope with any type of work regardless of size or weight . . . a source where skillful designing and advanced fabricating technique are supplemented by craftsmanship which assures you a smoother, finer appearing job embodying every advantage of Steel-Weld Fabrication. See Mahon's Insert in Sweet's Product Design File, or write for further information.

THE R. C. MAHON COMPANY

DETROIT 34, MICHIGAN

Engineers and Fabricators of Steel in Any Form for Any Purpose

MAHON



Any time you fly in a Martin 4-0-4, Superior tubing is probably working for your safety.

Once you're airborne, watch the 840-pound main landing gear assemblies flip forward and up with amazing speed, even though they may be working against a 180 m.p.h. drag. Fast landing gear retraction gives you an extra margin of take-off safety because "clean" aircraft have better flight characteristics.

Chances are your Martin 4-0-4 contains many feet of Superior ½" stainless steel tubing. In the hydraulic system, this tubing operates at a pressure of 3000 p.s.i., normally. On Martin's torture racks, it has demonstrated remarkable endurance under violent pressure surges at 1000 cycles *per second*, even around minimum bends.

Performance like this may well have a bearing on your production problems as well as on your personal safety. Superior's long experience in fine tubing, backed by highly-developed production equipment and extensive research and testing facilities assures you of top-quality small tubing for doing tough jobs well. Outline your own production problems in a letter to us, right now—we'll send you complete information and the appropriate Data Memo by return mail. Address: Superior Tube Company 2008 Germantown Ave., Norristown, Pennsylvania.

Round and Shaped Tubing available in Carbon, Alloy, and Stainless Steels, Nickel Alloys and Beryllium Copper.

Superior

THE BIG NAME IN SMALL TUBING

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331

All analyses .010" to ⅝" O.D.
Certain analyses (.035" Max. wall) up to 1⅜" O.D.

PLAY SAFE ON DEFENSE PRODUCTION
—Use these approved silver brazing alloys

Handy and Harman Brazing Alloys conforming to Standard Specifications

SOURCE OF NUMBER AND SPECIFICATION						HANDY & HARMAN	Silver Content of Alloys	Flow Points Degrees F.
MIL-S-15395 Ships-Amend 15 April 1951 Superseding Navy 47S13a	U. S. Navy Bureau of Aeronautics Spec. 47-S-13a	U. S. Army Spec. 57-97-1a	Federal Government Agencies Fed. Spec. QQ-S-561d	A.S.T.M. Spec. B-73-29	Society of Automotive Engineers Aeronautic Materials Spec.	Brazing Alloys and Silver Solders Corresponding to Standard Specification Numbers		
III	III	—	3	—	—	Sil-Fos Brazing Alloy	15%	1300
IV	IV	—	4	—	AMS4770	Easy-Flo Brazing Alloy	50	1175
V	V	—	5	—	—	Easy-Flo No. 3 Brazing Alloy	50	1270
VII	VII	VII	7*	—	—	Easy-Flo 45 Brazing Alloy	45	1145
VIII	VIII	VIII	8*	—	—	Easy-Flo 35 Brazing Alloy	35	1295
—	—	—	—	1	—	TL Silver Solder	9	1565
0	0	—	0	2	—	AT Special Silver Solder	20	1500
—	—	—	—	3	—	ATT Silver Solder	20	1500
I	I	—	1	4	—	DE Silver Solder	45	1370
—	—	—	—	5	—	ETX Silver Solder	50	1425
—	—	—	—	—	AMS4772	ED Silver Solder	54	1545
II	II	—	2	6	—	Easy Silver Solder	65	1325
—	—	—	—	7	—	Medium Silver Solder	70	1390
—	—	—	—	8	—	IT Silver Solder	80	1460
Navy Spec. 51F4a	Navy Spec. 51F4a	U. S. Army Spec. 4-1121	Navy Spec. 51F4a	—	AMS 3410	HANDY FLUX	—	Fluid 1100 to 1600

*Revisions of specifications pending covering Easy-Flo 45 and 35.

Municipalities and like government agencies doing government work may order under either Army, Navy or Federal specifications.

This table gives you the numbers of the standard specifications of the Army, Navy and other agencies, covering the various Handy & Harman silver brazing alloys.

You play *doubly* safe when you use these alloys. You're sure of their approval — and you're sure of the fast, reliable, low-cost brazing production they naturally provide.

GET THE WHOLE AMAZING STORY IN BULLETIN 20

This fact-packed bulletin gives full details about EASY-FLO and SIL-FOS, the low-temperature silver brazing alloys most widely used in defense production. Also contains useful info on joint design and fast brazing production methods. Write for a free copy.

Exceptional production rates are being obtained on thousands of jobs where the alloy is *preplaced* and brazing is automatic, as in the furnace application at left. Also, because of their low flow points and free-flowing properties, these alloys make hand torch brazing an extremely easy, fast operation. We'll give you a "no-obligation" demonstration in your shop on request.

HANDY & HARMAN — FOUNDED 1867 — QUALITY · SERVICE — ORIGINATORS OF EASY-FLO & SIL-FOS

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N. Y.

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Here's why it pays *to know your*

HSM
HONEYWELL SUPPLIES MAN

L. E. DOTTS, Honeywell Supplies Man in the East Orange, N. J. area, points out features of Brown instrument charts to Mr. James Forgione of the Heyden Chemical Corporation . . . explains that they're made of paper designed for clear, consistent inking, precisely calibrated for accurate recording.

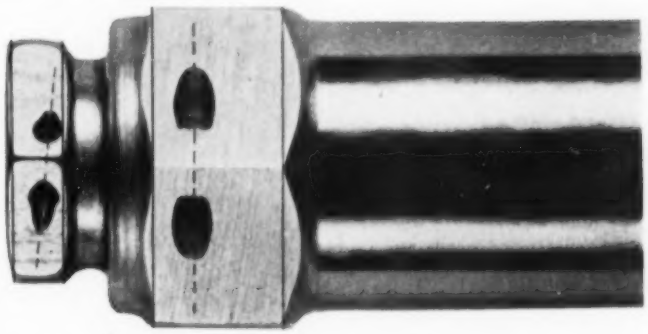
Planned buying, the HSM way, eliminates excessive storage time that often leads to chart moisture damage. And it helps you save money and maintain balanced inventories . . . not only on charts, but on *all* pyrometer supplies.

Get the full details from your local Honeywell Supplies Man, at your nearby Honeywell office . . . as near to you as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4503 Wayne Ave., Philadelphia 44, Pa. Immediate shipment from Philadelphia stocks.

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

Is this troublemaker causing headaches in your shop?



(Note that the cross hole drilled on the part to the left—without preliminary spot facing—is on an angle and is not parallel with the face of the part. Further, neither side of the drilled hole is clean. Now compare it to the straight, clean hole on the right, drilled after spot facing.)

DRILLING CROSS HOLES

Recognize this common troublemaker? It involves drilling cross holes through angular sides of a hexagon head. Some shopmen tell us this job invariably causes them grief from the standpoint of high drill breakage and excessive wear on drill bushings resulting in poorly drilled holes. So one of our stainless service engineers recommended this easy cure: Before drilling, spot face where the drill enters the work. A simple spot facing fixture will do it. In this case the customer's fixture for drilling was O. K. for spot facing and the only tool needed to do this job was a drill ground with a flat end or a regular spot facer. If holes must be exceptionally clean, both sides should be spot faced.

Getting the answers to fabricating problems like this is part of doing business with Carpenter!

Isn't it worth a lot to know that the Carpenter Stainless you order is backed by a competent field engineering service to make Stainless fabricating better, easier, more economical? That's the way Carpenter likes to do business! It's one of the surest ways you have to get Stainless fabricating results you've always wanted.

And along with this helpful service, Carpenter brings you the finest Stainless money can buy. Originating in the same mill that invented the first Free-Machining Stainless, it means Stainless that feeds through your machines the same today, tomorrow and a year from now. So for really dependable Stainless backed by helpful shop service, get in touch with Carpenter. THE CARPENTER STEEL CO., 133 W. Bern St., Reading, Pa.

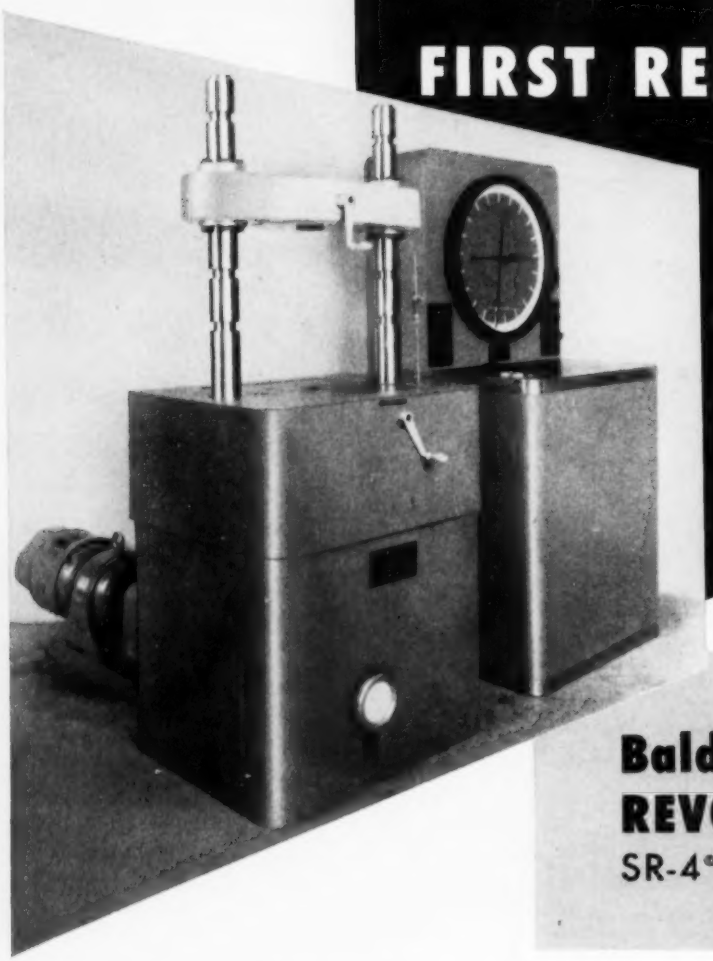
Export Department: The Carpenter Steel Co., Port Washington, N.Y. —"CARSTEELCO"

Carpenter STEEL

Free-Machining Stainless

takes the problems out of production

Call your nearest Carpenter Mill-Branch Warehouse, Office or Distributor



FIRST REAL ADVANCE

in materials testing equipment IN 20 YEARS

Baldwin-Emery's REVOLUTIONARY SR-4® testing machine

At Testing Headquarters, after five years of development, Baldwin-Emery's new SR-4 FGT Testing Machine is now being produced in quantity. The most versatile of all universal testing machines, incorporating an electric weighing system and electronically-controlled loading mechanism, it is the first really basic change in materials testing equipment in the past twenty years.

With a 50,000 lb. load capacity, this SR-4 FGT Testing Machine has these characteristics which contribute to its remarkable performance: a single reversing screw drive . . . a single convenient specimen location for both tension and compression tests . . . automatic cycling of load . . . high speed response to dynamic as well as static loads . . . extreme structural rigidity . . . ability to feed back output from the load cells and SR-4 extensometer for control purposes . . . ability to record load vs. strain statically with the Baldwin-Peters SR-4 recorder as well as dynamically with oscillographs or oscilloscopes.

IT IS THESE CAPABILITIES WHICH MAKE THIS MACHINE SO VERY VERSATILE:

1. Static tension, compression, flexure and torsion tests.
2. Top center zero for complete reverse load cycle.
3. Alternating load cycling for fatigue testing between fixed load points or fixed deflection points.
4. Shock tests on structures.
5. Creep, stress rupture, and relaxation tests.
6. As a straining frame for experimental stress analysis using Stresscoat, strain gages and photoelasticity.

To learn more about this new testing machine, please write for Bulletin 4202 to:
Dept. 2224, Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.

TESTING HEADQUARTERS

BALDWIN - LIMA - HAMILTON

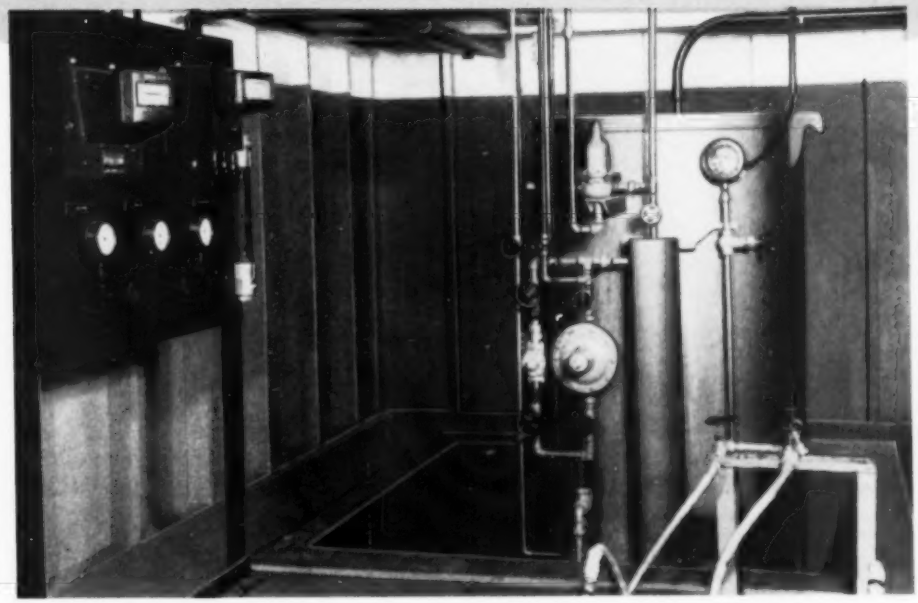
General Offices: Philadelphia 42, Pa. • Offices in Principal Cities

In Canada: Peacock Bros., Ltd., Montreal, Quebec

DREVER

AMMONIA DISSOCIATOR

produces **the ideal protective furnace atmosphere**



Shown at right is Drever 1000 CFH Ammonia Dissociator—panel complete with flow meter, pressure gauge, over-temperature protection instruments and temperature control, which is now furnished flush mounted.

"CRACKED" AMMONIA SHOWS TREMENDOUS COST SAVING and UNSURPASSED PERFORMANCE

1 —Bright Annealing — Stainless Steels, Nickel and Nickel Alloys, Beryllium Copper, Silicon Copper Alloys and Bronzes, and high and low carbon steels.

2 —Clean Hardening — High carbon and high chrome tool steels.

3 —Copper Brazing of all types of ferrous metals.

4 —Sintering of Powdered Metal Parts.

5 —Reduction of Metal Oxides.

6 —Bright Annealing of Electrical Steels.

7 —Atomic Hydrogen Welding.

8 —Radio Tube Sealing.

We can supply COMPLETE STORAGE SYSTEMS for tank car lots of anhydrous ammonia. This reduces the cost of ammonia approximately 75%.

● **GET ALL THE FACTS** about dissociated ammonia, pure, dry hydrogen and nitrogen. **Write today for Bulletin B-52 now on the press.**

DREVER CO

790 E. VENANGO ST., PHILADELPHIA 34, PA.

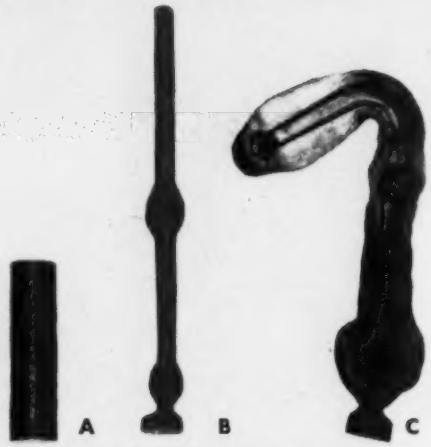
REDUCEROLLING THIS BELL CRANK FORGING BLANK—

1. Cuts labor cost in half . . .

2. Doubles production per man hour . . .

3. Saves one pound of steel per forging!

NO. 6 REDUCEROLL



Stock (A) measures 2¼" round by 8¾" long, weighs 10 lbs. REDUCEROLLED blank (B) ready for forging. Finished forging (C). Note small amount of flash.

METHOD	EQUIPMENT	CREW	FORGINGS PER 8 HOURS
OLD	Two Hammers	4 Men	575
NEW	One Hammer One Reduceroll	3 Men	900
RESULTS	Saves One Hammer	Saves One Man	Produces 325 More Forgings

From one of America's largest and most modern forge shops comes this report of outstanding progress in forging the steering bell crank illustrated above.

The REDUCEROLLING technique, in addition to producing 325 more forgings per eight hours, also obtains three extra forgings from each bar of stock, thus saving one pound of steel per forging. Rolls were redressed after pre-forming approximately 14,000 blanks. Same rolls have been redressed three times to date.

THIS DOOR IS ALWAYS OPEN!

Our entire organization is always at your service to help you solve your forging problems. Send us prints or samples of the parts you wish to forge. Better yet, visit us. No obligation, of course.

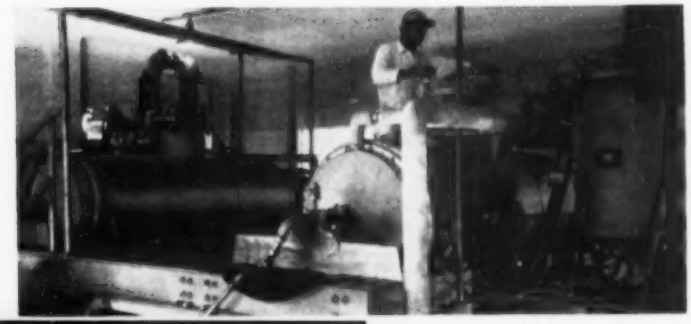
NATIONAL MACHINERY COMPANY

TIFFIN, OHIO—SINCE 1874

DESIGNERS AND BUILDERS OF MODERN FORGING MACHINES • MAXIPRESSES • REDUCEROLLS • COLD HEADERS • BOLTMAKERS • NUT FORMERS • TAPPERS • NAILMAKERS

Hartford Detroit Chicago

Operator removes boxes of tubular paper capacitors from Stokes Vacuum Impregnator at Pyramid Electric Co., North Bergen, N. J. Capacitors have been impregnated with mineral oil to improve stability and lengthen service life.



Installation of Stokes Rotary Vacuum Dryers used by Metals Disintegrating Co., Berkeley, California, for drying of aluminum powder. Highly oxidizable materials can be handled without any danger of combustion or explosion when processed in vacuum.

Operator transfers evacuated retort from heating to cooling station of Stokes Vacuum Annealing Furnace, built for processing, annealing and other heat treatment of titanium, zirconium, hafnium and copper.

Operator loads shell-frozen human blood plasma into one of the Stokes drying chambers of the lyophilizing plant at the Sharp & Dohme, Inc. biological laboratories, Glenolden, Pennsylvania.

There is no romancing about Vacuum at Stokes!

Vacuum processing starts with a vacuum-tight system and pumps to exhaust the air.

These are simple truths, the significance of which is never forgotten among men who have worked for many years in vacuum engineering.

Stokes men have many years of *engineering* experience, *shop* experience, *operating* experience in the design, construction and installation of vacuum processing systems.

But the absence of romancing in Stokes' thinking implies no want of imagination! Indeed, the practical application of vacuum processing—which gives us blood plasma, the "wonder drugs", costume jewelry, diesel locomotive motors, radio and electronic communication—had much of its inception in Stokes laboratories; takes practical shape in Stokes vacuum processing equipment for industry.

Stokes is FIRST in Vacuum . . . in great and small industrial plants, in schools, hospitals, and laboratories throughout the world.

F. J. Stokes Machine Company, Philadelphia 20, Pa.

STOKES

STOKES MAKES: High Vacuum Equipment, Vacuum Pumps and Gages / Industrial Tabletting, Powder Metal and Plastics Molding Presses / Pharmaceutical Equipment

Furnace linings last longer

when they are made of Norton-engineered Special Refractories

Fewer shut-downs and more continuous operation is always the story when linings are made of Special Refractories engineered to your job by Norton. Whether you are melting ferrous or nonferrous metals there are Norton mixtures for a wide variety of successful applications that mean more metal melted per lining, fewer furnace shut-downs and generally lower costs.

There are so many complications in metal melting, involving chemical, electrical and physical conditions it will pay you to take advantage of Norton's 40 years' experience in solving Special Refractory problems like yours.

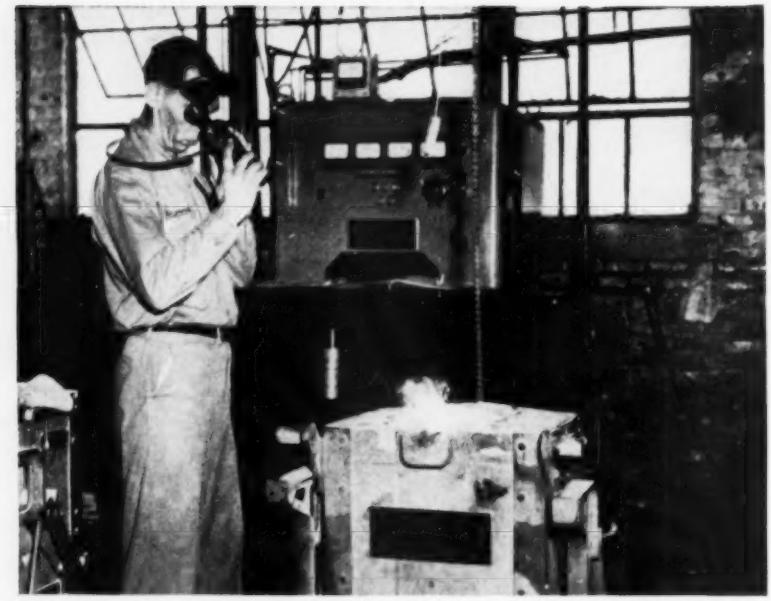
Many different materials

Norton furnishes Special Refractory grain, cements and bonded shapes in a wide variety of mixtures each engineered for a particular set of conditions.

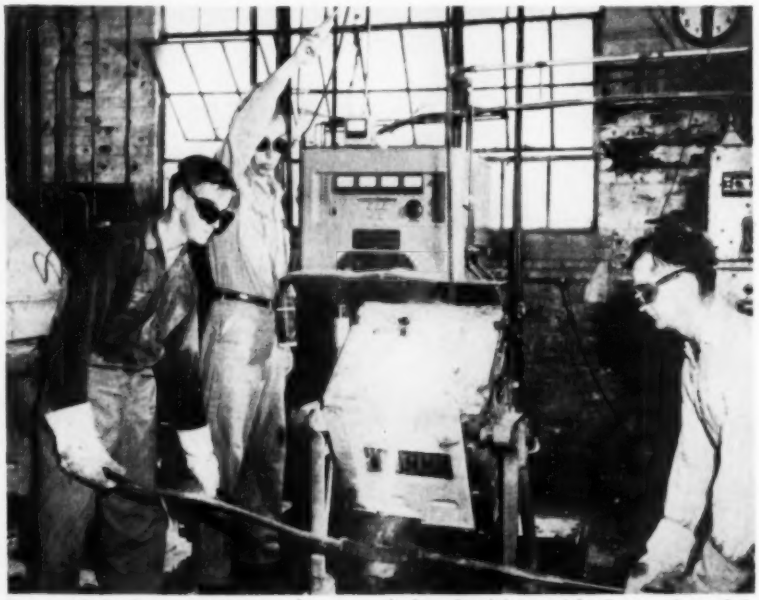
Such special Refractory Materials as CRYSTOLON* (silicon carbide), ALUNDUM*, FUSED STABILIZED ZIRCONIA.

What is your problem?

We believe you will benefit by consulting your nearby NORTON Representative or writing Norton Company, 323 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.



Taking the Temperature reading on the melt at the Metalmold Corporation plant at Groton, Mass. Temperatures go 3200° F. and higher. MAGNORITE* grain placed between the crucible and the coil has such high rammed density that it offers great resistance to penetration, erosion and chemical attack.



Longer Life for Furnace Linings can be expected when the right special refractory is used. In this plant they count on MAGNORITE to prevent short circuits in the event of crucible breakage. MAGNORITE keeps metal from reaching the primary coil of the furnace.

*Trade-Marks Reg. U. S. Pat. Off. and Foreign Countries

NORTON

Special REFRACTORIES

Making better products to make other products better

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Metal Progress . . . . . April 1953 Vol. 63, No. 4

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By HARRY B. KNOWLTON
Chief Engineer, Materials Engineering, International Harvester Co., Chicago
Chairman, Society for Automotive Engineers' Iron & Steel Technical Committee
Division VIII on Boron and Other Alternate Steels
Trustee, American Society for Metals

This discussion is based on data submitted by a number of users of boron steel to the Society of Automotive Engineers' Iron & Steel Technical Committee, Division VIII on Boron and Alternate Steels, as well as information on experiences of his colleagues in International Harvester Co., as brought out in meetings of the Engineering Materials Committee of that company. The author is chairman of both committees. Thanks are due to at least 40 men from 30 important consuming firms who have contributed generously to the S.A.E. committee's work. The author also wishes to acknowledge the help of many metallurgists throughout the International Harvester Co.'s plants. Finally, the Society of Automotive Engineers has kindly consented to the use of such material as has already appeared in SAE Journal *and its other publications.*

Experiences With Boron Steels in Production

IN THE LATTER PART of 1950 we in America were beginning to experience a critical shortage in certain elements, particularly nickel and molybdenum used in the production of common types of alloy steel. To alleviate this situation the American Iron & Steel Institute proposed two series of boron-treated Ni-Cr-Mo steels known as 80Bxx and 81Bxx, suitable to replace 86xx (0.50 Ni, 0.50 Cr, 0.20 Mo) and 41xx (1.00 Cr, 0.20 Mo) steels, respectively. The compositions of the new steels were lower in nickel and molybdenum than the steels being replaced and boron was added to bring the hardenability back up to the original. Similarly, 81B45 and TS86B45 (tentative standard) have been proposed as alternates for 4340 (1.75 Ni, 0.80 Cr, 0.25 Mo), while TS43BV14 and TS-94B17 have been used to replace such steels as 4815 (3.50 Ni, 0.25 Mo) and 4615 (1.75 Ni, 0.25 Mo).

About the same time, H. W. Logan and associates in the Wisconsin Steel Division of the International Harvester Co. created a complete series of 50Bxx (boron-treated 0.50% chromium steels) as alternates for 86xx steels of various carbon contents and for 9260 spring steel (2.00 Si). A little later, TS51B60 was proposed for the very heavy-duty springs having section thickness greater than 1 in., and 51B20 for certain case hardened gears formerly made of higher alloy steel.

In bolt manufacture, a carbon-boron TS14B35 steel had been successfully used by Caterpillar Tractor Co. as an alternate specification for oil quenched alloy steel bolts up to $\frac{9}{16}$ in. diameter, and water quenched bolts up to 1¼ in. diameter. Other variations of this type of steel were also proposed.

All the new steels were calculated to reproduce the hardenability ranges of the steels being replaced. The latter steels included in particular 86xx, 46xx, 41xx, 43xx and 48xx—in other words, steels having hardenability equivalent or superior to that of 86xx series. There were a number of automotive manufacturers, however, who were using steels such as the 40xx (0.80 Mn, 0.25 Mo) and the 13xx (1.75 Mn) series whose hardenabilities are less than that of 86xx. Consequently, the proposed 80Bxx and 81Bxx had higher hardenability than needed as alternates for those low-alloy steels already being used. [TS81xx (0.30 Ni, 0.40 Cr, 0.12 Mo) steels without boron were suggested as alternates for 40xx series.]

The National Production Authority has since permitted nickel contents up to 0.40% in heat

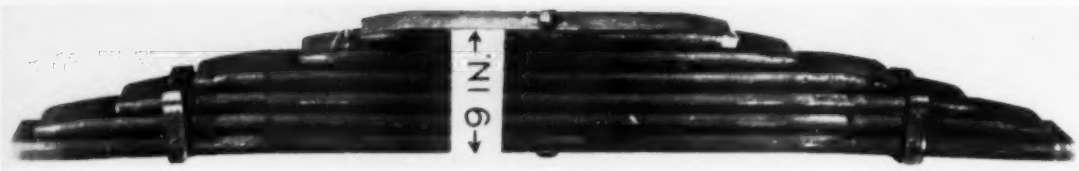


Fig. 1 — Heaviest Leaf Spring Made by International Harvester Co. An equalizer spring formerly made of 9262 steel (2.00 Si, 0.35 Cr) now made of TS51B60 (0.80 Cr, boron treated)

treating steels, and up to 0.60% in carburizing steels, as well as molybdenum contents up to 0.15% for all types of steels. Higher alloy steels are permitted only when such lean steels have been proved inadequate.

The Society of Automotive Engineers' Iron & Steel Technical Committee, Division VIII, was set up in 1950 to study the properties and applications of the new boron steels. The interest in this subject was so intense, and there were so many metallurgists who wanted to participate in development programs, that the meetings became open-forum discussions rather than closed committee meetings; attendance has been from 35 to 150. It was attempted to give everyone a place on the program who had anything tangible to present.

While there was a considerable variance of opinion expressed at the start, by the time of the meeting in December 1952 there seemed to be a rather general agreement on many points, although some others were still under dispute. The over-all situation can now be stated very briefly as follows:

(a) Alloy heat treating steels containing 0.40 to 0.60 carbon have been satisfactorily replaced by boron steels with equivalent hardenability. The alternates have not given any trouble so far as service performance is concerned. The consensus is that response to manufacturing operations such as forging, heat treating, welding, and machining has not been changed by substitution of low-alloy boron steels for the previously used steels slightly higher in alloy.

(b) Substitution of boron for all, or a portion, of the content of some other alloying element replaces only the *hardenability* effect of that element. It does not reproduce hot strength characteristics of certain elements. It does replace molybdenum in providing notch toughness at low temperatures, yet it has been found that certain boron steels are sometimes superior in this respect to some low-alloy steels of equivalent hardenability.

(c) The use of boron steels for case hardening in place of more conventional alloy steels presents a different type of problem, since the boron increases the hardenability of the low-carbon core greatly, and that of the lower-carbon portions of the case to some extent, yet it has very little effect upon the hardenability of the outer or high-carbon portions of the case. The increased hardenability of the core has sometimes produced excessive distortion, while lack of hardenability in the outer layers of the case may produce surfaces on large parts of insufficient hardness. Boron steels are being used satisfactorily, however, for certain types of gears and other case hardened parts.

These general propositions will now be elaborated in some detail, dividing the discussion into two main parts, namely, boron steels for heat treated parts (usually with intermediate carbon, from 0.30 to 0.60%), and boron steels for case carburized parts.

Fig. 2 — Observed Spread in Hardenability Curves From 131 Heats of TS50B60 (Hatched Area) in Comparison With Specified Hardenability Bands of the Standard Silico-Manganese Steels 9260H and 9262H

Element	TS50B60	9260H	9262H
Carbon	0.55/0.65	0.55/0.65	0.55/0.65
Manganese	0.75/1.00	0.70/1.05	0.70/1.05
Silicon	0.20/0.35	1.70/2.20	1.70/2.20
Chromium	0.40/0.60	—	0.20/0.50

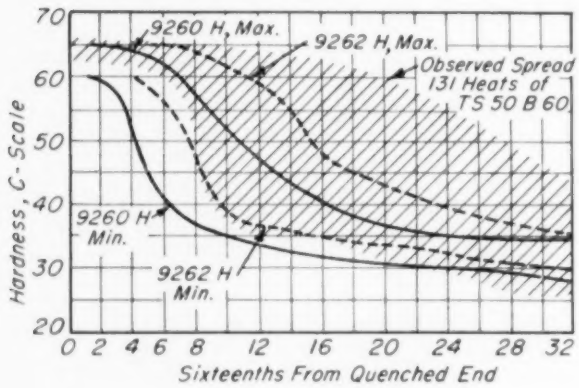


Table I – Typical Impact Properties
(A.S.T.M. Standard V-Notched Specimens)

Steel	Composition	Hardness	Energy Absorbed, Ft-Lb.	
			At +75° F.	At −40° F.
9262H*	0.90 Mn, 2.00 Si, 0.35 Cr	C-45	8	3.5
8655H†	0.90 Mn, 0.55 Ni, 0.50 Cr, 0.20 Mo	C-41	24	17
8650H†	0.90 Mn, 0.55 Ni, 0.50 Cr, 0.20 Mo	C-41	20.5	14
TS 50B60†	0.85 Mn, 0.50 Cr, B	C-41	25	17
80B60†	0.30 Ni, 0.45 Cr, 0.12 Mo, B	C-41	13	13
TS 51B60*	0.80 Cr, B	C-41	12	12
42B60*	0.50 Cr, 0.12 Mo, B	C-43	15.5	10

*Reported by Frank Sailer, International Harvester Co.
†Reported by E. T. Bittner, American Steel Foundries.

BORON STEELS FOR HEAT TREATED PARTS

Springs – As an example of the satisfactory substitution of boron steels on the basis of equivalent hardenability, it may be stated that International Harvester Co. has now used over 450 heats of TS50B60 steel for truck and tractor leaf springs, with leaf thicknesses up to 1 in., and a smaller but considerable number of TS51B60 heats for very heavy tractor springs with leaves over 1 in. in thickness (Fig. 1). The steels replaced were 9260H (2.00 Si), 9262H (2.00 Si, 0.35 Cr) and 4260 (0.50 Cr, 0.12 Mo). Heavy track springs ranging from 4½ in. diameter, 18 in. high, coiled from 1-in. rounds, to 7 in. diameter, 30 in. high, coiled from 1⅝-in. rounds, have been made of TS-50B60 by this company, replacing 8655 and 8660 (0.55 Ni, 0.50 Cr, 0.20 Mo). A number of other manufacturers are reporting similar success in coil springs.

The hardenability of the new boron-treated steels was in all cases equal or superior to that of the steels previously used. Laboratory fatigue and severe road testing showed as good performance for the boron steels as those previously used. More indicative of success is the fact that no field failures attributable to inferior material have been reported. While it might appear to be a step in the wrong direction to go from a silicon spring steel to TS50B60 containing 0.50% chromium, the latter analysis boron-treated eliminated costly reladling of the silicon steel in the steel mill and gave us a better and cleaner raw material.

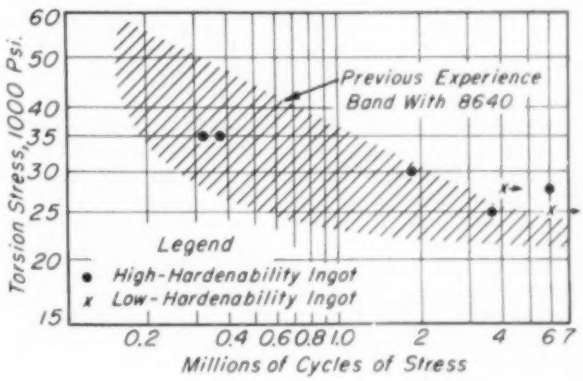
Our experience with springs answers the question which has frequently been asked, "Is it possible to produce boron steels as uniformly as other types of alloy steel?" Figure 2 shows the hardenability band for 131 heats of TS-50B60, in comparison with the specified hardenability band for 9260H and 9262H. It is quite apparent that the width of the hardenability band of the boron steel is as good as that of the 9262H silico-manganese steels up to 8/16 in. on the Jominy end-quenched bar.

Both the American Steel Foundries and the International Harvester Co. have reported better cold impact strength (more properly "notch toughness at subzero") for 80B60 and TS-50B60 steels than previously obtained with the respective members of the more conventional 92xx and 86xx series. See Table I.

Axle Shafts – G. C. Riegel and F. F. Vaughn of Caterpillar Tractor Co. have reported the use of about 20,000 tons of TS86B45 for axles and other heat treated parts. This steel was used primarily to replace 4340 (1.75 Ni, 0.80 Cr, 0.25 Mo). T. A. Frischman of Eaton Mfg.

Fig. 3 – Torsion Fatigue Tests on Rear Axle for Farmall-M Tractor Made of 50B49 Steels Give as Good Results as for the Conventional Higher-Alloy Steels Previously Used

Element	High-H Ingot	Low-H Ingot
Carbon	0.54	0.45
Manganese	1.00	0.80
Nickel	0.06	0.27
Chromium	0.25	0.32
Molybdenum	0.04	0.00
Boron	yes	yes



Co. also reports satisfactory performance of boron-treated steels in axle shafts, for which 81B45 has been used to replace 4147H (0.85 Mn, 1.00 Cr, 0.20 Mo) and 4340H (0.75 Mn, 1.75 Ni, 0.80 Cr, 0.25 Mo). Frank Sailer and C. O. Parish of International Harvester Co. have reported as good torsion fatigue properties for 50B49 tractor rear axles as previously obtained with 8640. See Fig. 3 and 4.

B. L. Johnson and W. E. Day of Mack Mfg. Co. have also reported good performance for 81B45 for 2½-in. diameter shafts. Many other heat treated parts have been made from boron steels, and the consensus is that where hardenability is the main criterion, boron steels can be used in place of more conventional types of alloy steel if the hardenability of the original steel is duplicated for the proper distance along the end-quenched test piece.

Workability – There have been some differences of opinion with regard to the response of boron steels to manufacturing operations. One metallurgist has reported greater freedom from quenching cracks when using boron steels; some have claimed greater machinability. On the other hand, some have reported more difficulties with the boron steels. The consensus, however, seems to be that there is no marked difference between the forging, machining, welding, or other manufacturing characteristics of a boron steel when compared to another of similar hardness and hardenability. The response of boron steels to normalizing and annealing operations is the same as that of a steel of the same base analysis; however, if boron is used to replace some element which has a considerable effect upon the critical points (transformation ranges) it is obvious that proper allowances should be made in the heat treatment schedule.

Toughness – Some metallurgists have preferred to modify chemistry in some other way so as to maintain the original hardenability, rather than to add boron to a low-alloy steel – for example, replace 4140 with TS4140, thus saving about half the molybdenum by adding a few points of manganese and chromium.

Fig. 4 – (Top) Tractor Engine Clutch Shaft, 14½ In. Long, Splined Diameter 2 In. It is made of 50B49, heat treated all over, and smooth portion further induction hardened. The track frame pivot shaft below is 5 in. diameter and 8 ft. long; 50B49 replaces TS4145. Black areas are induction hardened

Obviously, the good effect of the higher molybdenum on the good cold notch toughness is not reproduced by the addition of chromium. It was reported that the impact strength of TS4140 after heat treating to about 277 Brinell was 16 to 35 ft-lb. at –40° F., instead of a minimum of 40 ft-lb. which is demanded by some specifications for parts made of this steel. Subsequent tests with 42B40, a boron-treated steel low in chromium and molybdenum,* gave values over 50 ft-lb. As far as impact properties at low temperatures are concerned, 42B40 is at least equal to 4140, and definitely better than TS4140.

It should be emphasized that many applications do not absolutely need these extremely high figures for cold impact strength. For example, 9260 and 5160 have been used for automotive leaf springs for many years with satisfactory results, even in very cold climates; their cold impact strength is quite low. Rail steel would never be used if rails were appraised by notched-bar impact tests. It should be remembered that the impact test is usually

*Editor's Footnote – At the Dec. 3, 1952, meeting of S.A.E. Division VIII a series of four nickel-free steels were recommended as worthy substitutes for medium carbon grades of 41xx steels, and in February 1953 the American Iron & Steel Institute issued "Interim Grades" 42B35, 42B40, 42B45 and 42B50, containing 0.70 to 1.00% manganese, 0.40 to 0.65% chromium, and 0.08 to 0.15% molybdenum. Data for 42B40 presented to the S.A.E. meeting indicated that it is free from susceptibility to quench cracking and has hardenability equal to 4140 or to TS4140 as far as 1 in. on the Jominy test (about equivalent to the cooling rate of a 3½-in. round in an oil quench). Both steels heat treated in various ways to C-33 hardness had about 55 ft-lb. Charpy V-notch impact in oversize specimens, tested at room temperature, except that when air cooled through the temper-brittleness range the 4140 tested 52 ft-lb. compared with 57 ft-lb. for comparable tests on 42B40. Test pieces heat treated to C-30 also had equivalent Charpy toughness at zero and –40° F.; one heat of 42B40 appeared to be markedly tougher than 4140 at –100° F.

made on a sharply notched bar, which in itself tends to induce "brittle performance". If a specimen with a round groove simulating an average commercial fillet is compared to a sharply notched bar it would probably not be brittle in the impact test until a much lower temperature is reached.

There is no question, however, but that all steel requires a certain amount of toughness, and parts which are to be used in subzero surroundings must be "tough" at those temperatures. Test pieces should simulate the finished part under consideration; *then* the performance of that part may be estimated; otherwise we merely have the performance of an arbitrarily notched specimen. The low-alloy boron steels will usually have somewhat better cold notch toughness than some types of alloy steel, but probably not as good as those containing more than 0.20% Mo, other things being equal.

It is contended by some, however, that boron neither adds nor detracts anything in toughness from the base composition, except in that the boron increases the hardenability, and consequently tends to produce a higher percentage of martensite in the as-quenched condition. It is well known that the maximum toughness is obtained only with a high per cent of martensite before tempering.

Machinability – There have been somewhat divergent reports on the effect of boron upon the machinability of steel, but it is the general opinion that boron has not affected machinability in either way, except indirectly as it has affected the hardenability. This seems quite logical, as the addition of about 0.001% of boron does not produce a discernible constituent under the high-power microscope.*

Bolts – G. C. Riegel and F. F. Vaughn of Caterpillar Tractor Co. have reported the use of 30,000 tons of TS14B35 (formerly known as 10T35) for bolts prior to 1951. These were used for oil quenched bolts up to $\frac{9}{16}$ in. diameter and for water quenched bolts from 1 to 1¼ in. diameter. Since then this type of steel has been in fairly common use in the bolt industry, replacing low-alloy steels such as 4035 (0.80 Mn, 0.25 Mo). For bolts with heads that are difficult to form, TS40B37 (which is a boron-treated 4035 with molybdenum reduced to the 0.08 to 0.15% range) has worked more satisfactorily.

Armor Plate – Probably the most difficult problem with heat treating grades of steel has been the duplication of the high hardenability of 4340 (high Ni-Cr-Mo) and similar steels. As previously stated for axle shafts, Caterpillar Tractor Co. has successfully used TS86B45. At the December 1952 meeting of Division VIII, Major Marsten reported research work on 90B40 + vanadium, and 98B40 + vanadium.

Arthur Jones of Watertown Arsenal also reported the successful use of a manganese-boron type of steel for armor plate up to 3 in. in thickness. This material passed ballistic tests satisfactorily after welding. He emphasized the importance of good low-temperature impact properties, which have an established relationship with good ballistics of guns and armor – that is, resistance to high-speed impact.

CASE HARDENING STEELS

Gears – About half of the 750,000 tons of boron steel produced in 1952 has been used for case hardened parts with satisfactory results, the great majority of it in gears. Mention should be made of the successful use, by W. E. Day of Mack Truck, of 43BV14 in place of 4820 for heavy-duty pinions; the substitution by J. C. Mertz of Pratt and Whitney of 43BV12 for 9310, for gears, shafts and couplings; and the use of 46B12 in place of 4812, by N. J. Clark of Reed Roller Bit Co., for rock bit cutters. R. W. Roush of Timken, T. A. Frischman of Eaton Axle and others have used 94B17 as a substitute for 4620 and 4820 for gears and pinions.

It must not be inferred, however, that boron steels can be used for any particular design or application of case hardened gears without careful study of the problems involved. The major portion of the time at the Division VIII meetings has been devoted to this point.

The reason why there is more difficulty with the carburizing grades than with the heat treating grades of boron steels is that boron

*Editor's Footnote – Machinability may give trouble if the innate characteristics of the boron-treated steels are not given due consideration. For example, G. C. Riegel of Caterpillar Tractor Co., who has used boron-treated steels in a large way for 10 years or more, writes:

"The principal difficulties which we have encountered in the use of the boron-treated steels in the low-carbon grades for case hardened gears have been due to the excessive softness after annealing. This has given trouble with hobbing, shaping and broaching. On the other hand, in some of the applications in which boron was used as a hardening agent in steels above 0.50% carbon, we have had the problem of trapping so much austenite in the quenched part that we have had difficulty in obtaining the hardness without additional expense in heat treatment. In other instances, quench cracking has been aggravated by the late transformation within the body of the part."

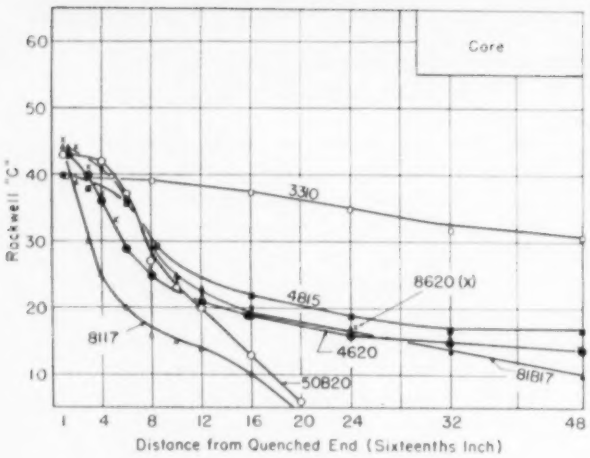


Fig. 5 – Core Hardenability of Seven Carburizing Steels (Kayser, Thomson and Boegehold)

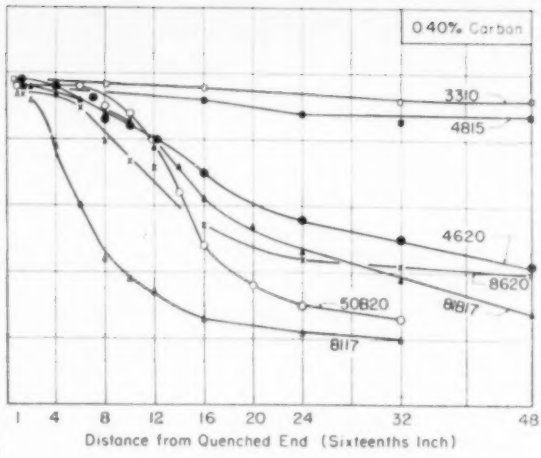


Fig. 6 – Hardenability of the Same Seven Steels as Fig. 5 When Carburized to 0.40% Carbon (End Quenched From the Pot at 1700° F.)

has a vastly different effect upon the hardenability of the low-carbon core and the high-carbon case. It was early brought out by Grange, Wray and others, that the effect of boron on the hardenability of steel decreased with higher and higher carbon, and became practically nil at 0.90 to 1.00%. The exact quantitative effect has been questioned by other investigators, but all have agreed that its effect on hardenability is very low for steels of eutectoid composition or higher carbons. Some metallurgists have gone on the principle that steel could be selected for case hardened gears on the basis of the hardenability of the core; this works out fairly well for any type of alloy steel in which the hardenability is proportional to the carbon, but obviously has not worked so satisfactorily with regard to the boron steels.

The picture becomes further complicated when we consider that the carbon content in the "case" decreases from the surface to the beginning of the "core", and that the effect of boron upon hardenability varies at each level of carbon. This is brought out most clearly in the paper entitled "An End-Quench Test for Determining the Hardenability of Carburized Steels", presented by F. X. Kayser, R. F. Thomson and A. L. Boegehold at the 1952 ASM convention. The following section is a digest of the information in this paper.

New Test Bar – The usual manner of testing

Fig. 7 – Case Hardenability of the Seven Steels at the 0.60% Carbon Level

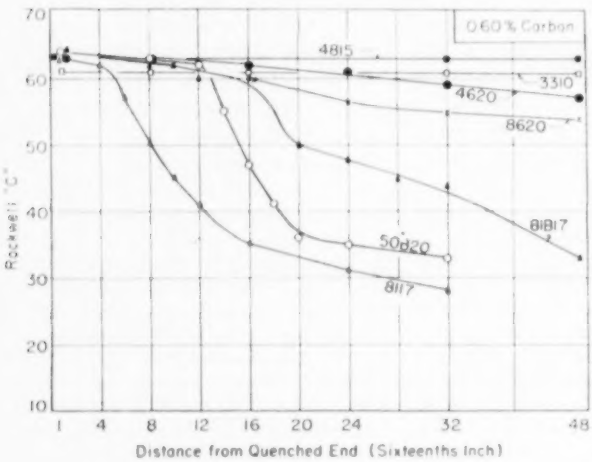
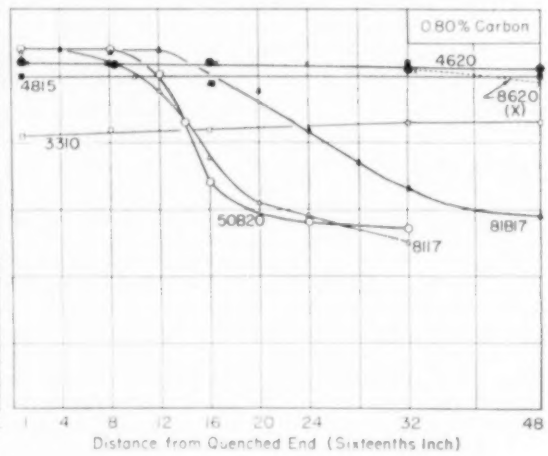


Fig. 8 – Case Hardenability of the Seven Steels at the 0.80% Carbon Level



the hardenability of case hardening steels has been to carburize a standard Jominy bar (a 1-in. round, 4 in. long), end-quench this bar, grind the cylindrical surface to predetermined case depths, each time making the standardized hardness survey. Messrs. Kayser, Thomson and Boegehold cite several disadvantages of this practice and propose instead a wedge-shaped bar, originally 0.70 in. square by 3.87 in. long, two of whose opposite sides are ground to a 4° taper. This bar is copper plated except on the tapered surfaces, carburized, end-quenched from the pot, the copper plate removed from the top (uncarburized) surface, which is etched lightly to determine whether carbon has leaked through, and then polished (finishing with a 6-micron diamond-impregnated wheel). Hardness surveys across the top flat are made at various distances from the quenched end, impressions being made by a Tukon hardness tester with Vickers diamond pyramid indenter and 3000-g. load, spaced 0.005 in., and converted to Rockwell C-scale measurements. To correlate the test positions with carbon content, the test piece is softened, straightened to 0.0005 in., and light millings from the tapered side are analyzed for carbon.

Table II – Chemical Analysis and Austenite Grain Size of Carburizing Steels Studied in Fig. 5 to 8

A.I.S.I. Type	C	Mn	P	S	Si	Ni	Cr	Mo	B	Grain Size
8620	0.20	0.86	0.029	0.026	0.27	0.53	0.57	0.19	–	7-8
8117	0.20	0.77	0.016	0.029	0.29	0.42	0.39	0.10	–	7-8
81B17	0.19	0.74	0.010	0.028	0.30	0.41	0.40	0.10	0.0012	7-8
50B20	0.20	0.94	0.015	0.028	0.31	0.06	0.47	0.01	0.0013	6-8
3310	0.13	0.54	0.005	0.010	0.28	3.46	1.68	0.06	–	7-8
4620	0.18	0.57	0.017	0.035	0.31	1.96	0.21	0.25	–	7-8
4815	0.13	0.43	0.015	0.020	0.25	3.58	0.16	0.26	–	4-5

Using this technique, the seven grades of commercial carburizing steels shown in Table II were studied, and Fig. 5 to 8 summarize the results of the investigation.

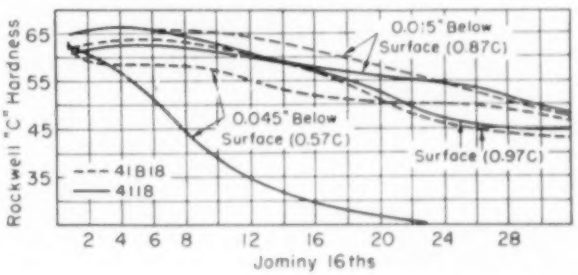
It will be noted in Fig. 5, for example, that the hardenability of the cores of 4815, 8620, and 4620, are nearly enough equivalent to justify interchangeable application of these steels for heavy-duty case hardened gears, provided core hardenability were the only requirement. At the 0.40% carbon level shown in Fig. 6, which represents the lower layer of any carburized case, it will be noted that the hardenability of 4815 is vastly greater than that of 4620 and 8620. This is particularly true at distances greater than 8/16ths from the quenched end of the Jominy specimen, which represents the speed of cooling produced on the surface by oil quenching rounds 3 in. in diameter or greater, or the cooling speed at ¾ radius on oil quenched rounds more than 2 in. in diameter.

It is probable that the cooling speed at the root of the teeth of 2-in. round pinions corresponds fairly closely with that of the ¾ radius position of the 2-in. round oil quenched bar – that is to say, at the same speed as the end-quenched bar 8/16 in. from the end. On this basis, the graphs in Fig. 6 indicate that there would be little difference in the hardenability of the 0.40% carbon layer of the case for pinions less than 2 in. diameter, regardless of which type of steel is used. It follows that if hardness and strength of the 0.40% carbon zone in the case are necessary to prevent pitting or spalling of case hardened gear teeth, these three steels cannot be used interchangeably for large pinions. Only at regions near the inner layers of the case does this lag in hardenability of 4620 and 8620 occur, for Fig. 7 and 8 show that the hardenability of the 0.60 and 0.80% carbon layers is approximately the same for all three of the steels.

As stated before, it is the general impression that boron produces a great effect upon the hardenability of the core, a considerable increase in the hardenability of the 0.40% carbon layer at the bottom of the case, and little or no effect upon the surface layers or high-carbon portion of the case.

This is not exactly borne out by the lines in Fig. 5 to 8 for 8117 and 81B17 steels. At the 1/16-in. position no significant differences exist, but the authors say "at the 4/16-in. and

Fig. 9 – Hardness Surveys at Various Levels of Carburized Jominy Bars, End Quenched. Samples taken from a split heat of 4148



still more at the 8/16-in. position, the effect of boron becomes great, first causing an increase in hardness in the core and in the lower-carbon regions, and then at slower cooling conditions, having its greatest effect at progressively higher carbon concentrations. It appears to have its maximum effect on the hardenability of 81B17 at about 0.70% carbon. Our data also clearly indicate that at 1% carbon both steels are of comparable hardenability."

The present writer presented a discussion of this paper by Kayser, Thomson and Boegehold in which he cited some information gathered by Frank Sailer of International Harvester Co. summarized in Fig. 9. He studied a split heat of 4118 (0.21% C, 0.96% Mn, 0.30% Si, 0.15% Ni, 0.46% Cr, 0.15% Mo), part of which was boron treated. The curves show hardenability of a carburized Jominy bar, successively ground and tested at various depths below the surface. There is very little difference in hardness at the surface, considerable difference in favor of 41B18 at 0.015 in. below the surface, and quite a great difference 0.045 in. down.

Desired Properties for Gears – For good performance of case hardened gears it is generally agreed that the case must be at least C-57 hard at the roots of the teeth – even midway between the sides of the gear – to guarantee adequate bending fatigue strength of the teeth. (There may be some exceptions if the working stresses are very low and surface hardness is only intended to prevent wear; this might apply to worms, where the root is so thick that bending fatigue failures never occur.) It is also agreed that the entire working surface of the gear tooth must be C-57 or above.

There is more difference of opinion with regard to the desirable hardness at different points on the cross section of both case and core. It is contended by many metallurgists that a certain minimum core hardness is required to support the case and prevent both spalling and breaking; the actual hardness probably varies with the depth of case and the magnitude of stress. They also contend that high core hardness is likely to cause brittleness in the teeth.

On the other hand, it has been reported by others that the residual stresses produced by heat treatment are one of the largest factors governing the performance of the gears. Low core hardness may be associated with the fact that the core has passed through heat treatment without forming a high percentage of martensite in the microstructure, and consequently has not dilated; in extreme instances the core might contract continuously during quenching, even after the case is fully hardened, and this contraction of the core would set up desirable compressive stresses of the surface of the case. On the other hand, high hardness in the core may be associated with the formation of martensite *in the core* after the case is hardened, with the result that dilation of the core produces undesirable tensile stresses in the case – leading to quench cracks. Changes in the case depth and quenching treatments sometimes can alter the stress condition from tension to compression.

On the whole it may be said that the boron steels are inclined to attain the higher hardness in the core, and consequently have sometimes given trouble with distortion of the gear teeth. In some instances this has been corrected by lowering the initial carbon content of the core. Others have reported, however, that such low-carbon steels are very difficult to machine.

From this discussion it may be apparent that the gear maker encounters more problems in satisfactorily substituting boron steels for other alloy steels than do metallurgists in other consuming industries. Sometimes this substitution is not to be recommended. In many other instances, however, boron steels have been used satisfactorily in important gears.

SUMMARY

In concluding, it may be stated that approximately 750,000 tons of boron steel were produced in 1952, and used satisfactorily as alternates for other alloy steels. This amounted to approximately 10% of the alloy steels produced for engineering purposes. In 1952 the International Harvester Co. converted about 59% of its alloy steels to boron steels containing somewhat lower percentages of the other alloys. It must be remembered, however, that this was in materials having hardenability equal to or above that of 86xx. A great deal of the passenger car industry is using such series as 13xx and 51xx, whose hardenability is *lower* than that of 86xx, and boron steels of the type of 50Bxx and 80Bxx are not needed. We do not yet know much about boron steels of such low hardenability except for applications as bolts. It might be possible to develop such steels when and if they become necessary to conserve the last pound of alloying elements.

By H. H. MILLER
Assistant Chief Metallurgical Engineer
Buick Motor Division, Flint, Mich.

Standards Ease Selection and Use of Carbide Tool Materials

STEADY increase in the acceptance of sintered carbides for metal-cutting and wear applications has complicated the problem of selecting the best available material for a specific use. The task is made no easier by the expanding numbers and types of carbides offered by suppliers, nor by the fact that the same material may exhibit varying performance characteristics from machine to machine. Sensitivity to cratering and wear, along with the influence of factors such as chemical analysis, hardness, grain size, specific gravity, porosity and transverse rupture strength, makes the choice of the optimum grade far more difficult with carbides than it is with high speed toolsteels.

As of today, if broaches, hobs, drills and taps are excluded, an estimated 80 to 85% of all tooling is of the carbide type at Buick Motor Div., General Motors Corp. This may appear high, but it reflects the insistent demands of the automotive industry for higher speeds, feeds and precision to promote lower machining costs, as well as the willingness to invest in new machine tools with sufficient ruggedness and rigidity to accommodate carbide tooling efficiently. As older machines continue to be replaced, it is inevitable that the use of carbide tooling will be increased.

The combination of properties possible with the various mixtures of tungsten, tantalum, columbium and titanium carbides (with metallic cobalt as the binder), naturally has resulted in a large number of different grades being offered to industry by the established suppliers of the material. The practice has been for each firm to identify its grades by its own symbols. The confusion from similar grades having many different source symbols has emphasized the desirability of a uniform classification system.

This fact was recognized at least ten years ago, when Oscar Strand, Buick's tool supervisor, originated a chart for classifying sintered carbides according to applications. There were actually 63 types of material used by Buick at that time, so Strand proposed to consolidate all of them into ten groups, each with a code number, as follows:

TC-1 – Roughing cuts on cast iron, non-

Table I – Comparison Chart Coordinating Old TC Symbols With New Identifications

Buick Code	Carbide Manufacturer								
	1	2	3	4	5	6	7	8	9
TC-1	CQ-1	CQ-1	CQ-1	CU-2	CQ-1	CQ-1	CQ-12		CQ-12
TC-2	CQ-2	CX-1	CQ-2	CU-2	CQ-2	CQ-2	CQ-2	CQ-2	CQ-2
TC-3	CZ-6	CQ-3	CQ-3	CX-8	CQ-3	CQ-3	CQ-3	CQ-3	
TC-4	CQ-4	CQ-4			CQ-4	CQ-4	CQ-4		
TC-5	CZ-1	CZ-1	CY-12	CW-1	CY-12	CZ-1	CY-12	CY-1	CY-12
TC-6	CY-3	CZ-4	CY-4	CW-5		CY-3	CY-5	CY-5	CY-3
TC-7	CZ-2	CY-7	CY-5	CW-3	CZ-2	CZ-3	CY-2	CY-7	CY-6
TC-8	CZ-5		CY-6						
TC-9	CQ-1	CQ-1	CQ-1	CU-2	CQ-1	CQ-1	CQ-12		CQ-12
TC-10	CQ-5	CQ-6	CQ-14	CU-1	CQ-8	CQ-6	CY-4	CQ-5	CY-3

Fig. 1 – Tungsten-Cobalt Sintered Carbide of CQ-1 Grade Is Relatively Coarse-Grained, Predominating Size Being 3 Microns. Etchant: alkaline $K_3Fe(CN)_6$. 1500 ×

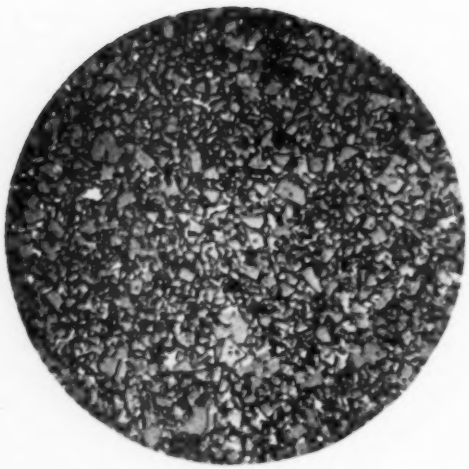


Fig. 2 – Tungsten-Cobalt Sintered Carbide of CQ-2 Grade, Grain Size 1 to 2 Microns. Suited for general-purpose machining of cast iron, nonferrous materials and stainless steels. 1500 ×

ferrous materials; cutter blades; also carbide parts to resist wear, other than TC-9 and TC-10.

TC-2 – General-purpose machining of cast iron, nonferrous materials, stainless steels; also reamer and cutter blades.

TC-3 – For light finishing cuts on cast iron and nonferrous materials.

TC-4 – For precision boring of cast iron and nonferrous materials.

TC-5 – Roughing cuts on steel.

TC-6 – General-purpose machining of steel.

TC-7 – Finishing cuts on steel.

TC-8 – Precision boring and light finishing work on steel.

TC-9 – Wear resistant materials, such as centers, rest blades and gages.

TC-10 – Wear resistant materials involving light shock.

The "TC" designation, of course, stands for tungsten carbide. Each of ten suppliers was asked for grade recommendations for the applications involved and a chart was drawn up to assist in blueprint and ordering activity. It reduced from 63 to ten the symbols necessary to specify carbides.

Several years of study and experience with the system revealed a number of inadequacies:

1. It proved next to impossible to realize any uniformity of thinking as to what constituted a "roughing" or a "finishing" cut. The terminology was not compatible with differences encountered in going from one process to another.

2. Although the classification chart indicated equality from one manufacturer to another for the same grade, this was not actually true.

3. Properties of a particular carbide could be changed by the manufacturer without informing the user, resulting in a loss of control over applications.

4. A recommended grade could change position on the chart, necessitating constant attention to revisions.

5. Manufacturers' grade symbols were meaningless insofar as chemical, mechanical and physical properties were concerned. Thus, there were no quality standards for the user to inspect carbides or investigate tool failures.

To throw more light on the whole matter of carbide tool application, two programs were initiated by the Buick organization about five years ago. One was aimed at obtaining all possible shop information and data on tool failures, abuses in grinding, brazing and on general performance. The second involved metallurgical research into the properties of various available carbide grades, so that some dependable form of inspection could be evolved. In the latter work, suppliers of sintered carbides contributed to an important degree, realizing that progress toward standardization would benefit them in the long run.

A major accomplishment of these two extended research projects was a new classification based on these properties: Chemical composition, hardness, specific gravity, transverse rupture strength, porosity and microstructure. The four most useful in the inspection of carbide materials are hardness, specific

Fig. 3 – Tungsten-Cobalt-Titanium Sintered Carbide of CY-3 Grade. Predominating grain size is 4 to 3 microns. It is recommended for general-purpose machining of steel. 1500 ×

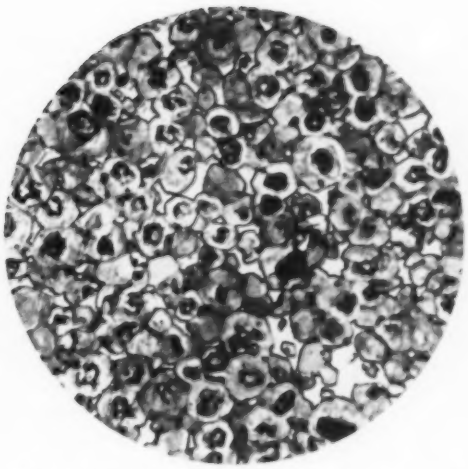


Fig. 4 – Tungsten-Cobalt-Tantalum-Titanium Sintered Carbide of CZ-5 Grade. Suited to precision boring jobs, its high titanium (25.59%) and tantalum (9.38%) provide excellent wear properties but make grinding difficult. 1500 ×

gravity, porosity and microstructure. For the purposes of classification, however, the nominal chemical analysis offers an easy approach.

Basically, there are four types of sintered carbides – tungsten carbide plus metallic cobalt; tungsten carbide plus tantalum carbide plus cobalt; tungsten carbide plus titanium carbide plus cobalt; and tungsten carbide plus tantalum carbide plus titanium carbide plus cobalt. Two newer groups have now been added to the classification, namely, the double and triple carbide mixtures, with cobalt binder and small percentages of columbium carbide. In each basic group there are a number of grades, with varying percentages of the constituents mentioned.

Table II on page 78 shows these six groups, covering a total of 51 grades. Only 29 are used by Buick, but all are available to the trade. It will be observed that letter symbols and numbers have been assigned to each grade, the letters referring to the basic chemical composition. The numbers do not indicate anything insofar as chemical analysis is concerned, being merely an arbitrary successional designation. Numbering the grades in this way allows the easy addition of more types as they may be developed. The system also is adaptable in that, if materials of different chemical analysis are to be classified, they can be grouped under other sets of letter symbols – chromium carbide, for example, might be CR.

Large numbers of blueprints in use throughout the Buick organization now carry the old "TC" designation for carbide tool usage. It might at first be thought that a switch to the new system would be confusing to designers and engineers. However, this has not occurred, for the TC symbols can be retained on drawings and, by consulting a simple comparison chart (Table I on p. 75) coordinating the TC symbols and the new identifications, the correct grade can be quickly selected.

At this stage, the classification system is nothing more than a recommended standard for carbides. Much of the data on properties have been furnished by suppliers as nominal values. Where Buick has developed the information, values also are considered nominal. Eventually working limits can be set for each carbide by close cooperation with sources. In the meantime, standards will serve as a guide in acceptance inspection and in the investigation of machining difficulties. They are in no sense intended as an attempt to tell manufacturers how to make the product, but once a certain grade is stabilized and applied it should not be changed without consulting the user. Generally speaking, when a carbide is changed significantly in constitution it will simply mean a new classification symbol.

Standards sheets for the different carbides, as now drawn up, include in addition to the data presented herewith typical microstructures at 1500 ×. Figures 1 to 4 are representative micrographs from the series of 51. The principal value of micrographs is to iden-

tify grades and determine quality. Predominating grain size can be measured by comparison with a standard grain-size chart (Fig. 5), reproduced here as it appears in the General Motors Book of Standards, serial G.M. 4454-P, released in May 1950.

This standard also gives recommended procedures for metallographic testing of carbides, including such things as sample preparation, treatment (including etching and electroleaching) and examination. Standard porosity charts also are appended, for comparison with unetched samples at 200 ×.

Etching of polished carbide samples is done in a fresh 1:1 mixture of 10% potassium hydroxide and 10% potassium ferricyanide in

Table II – Buick's Identification System and Classification Standards for Sintered Carbides

Carbide Grade	Nominal Composition, %						Rockwell Hardness, A-Scale†	Density,‡ g. per cc.	Predominating Grain Size, μ at 1500 ×	Transverse Rupture Strength, Psi. (000 Omitted) §
	W	Co	Ta	Ti	Cb	C*				
Tungsten-Cobalt										
CQ-1	88.25	6.0				5.75	91.2	14.95	3	180 to 275
CQ-2	88.25	6.0				5.75	91.8	14.95	1 to 2	180 to 260
CQ-3	89.66	4.5				5.84	92.2	15.05	1 to 2	140 to 250
CQ-4	91.06	3.0				5.94	92.8	15.15	3 to 2	125 to 225
CQ-5	85.43	9.0				5.57	90.3	14.60	1	275
CQ-6	81.68	13.0				5.32	88.0	14.25	4 to 3	300
CQ-7	85.43	9.0				5.57	89.5	14.55	2 to 4	250 to 350
CQ-8	76.98	18.0				5.02	87.5	13.65	1 to 3	340
CQ-9	70.41	25.0				4.59	85.5	13.25	2 to 3	300 to 450
CQ-10	78.86	16.0				5.14	86.0	13.85	2 to 3 and 8	300 to 425
CQ-11	82.61	12.0				5.39	86.5	14.30	3 to 5 and 7	280 to 375
CQ-12	87.31	7.0				5.69	91.0	14.89	2 to 4	240
CQ-13	75.10	20.0				4.90	86.0	13.60	2 to 4	380
CQ-14	83.55	11.0				5.45	89.3	14.28	2 to 3	300
CQ-15	79.80	15.0				5.20	88.0	14.00	1 to 2	390
Tungsten-Cobalt-Tantalum-Columbium										
CU-1	80.7	11.9	1.4		0.6	5.4	90.0	14.10	1 to 3	325
CU-2	86.3	5.8	1.8		0.3	5.8	92.0	14.80	2 to 3	250
CU-3	65.7	25.0	3.1		1.5	4.7	85.0	12.80	1 to 3	360
CU-4	71.7	20.0	2.7		0.9	4.7	86.5	13.40	1 to 3	380
CU-5	77.0	16.0	1.5		0.3	5.2	87.5	13.90	1 to 2	385
Tungsten-Cobalt-Tantalum-Titanium-Columbium										
CW-1	68.9	10.7	5.4	6.7	1.6	6.7	91.0	11.90	2 to 4	300
CW-2	65.0	8.8	5.8	11.0	1.8	7.6	91.5	11.10	2 to 4	250
CW-3	72.3	6.7	7.0	4.9	2.3	6.8	92.0	12.45	2 to 3 and 6	250
CW-4	67.0	6.0	7.2	10.9	2.4	7.4	93.0	11.50	5 to 7 and 2	200
CW-5	75.3	8.5	5.2	3.2	1.6	6.2	91.5	12.90	2 to 4	275
Tungsten-Cobalt-Tantalum										
CX-1	84.96	6.5	2.81			5.73	91.5	14.75	3	250
CX-2	69.47	6.0	18.76			5.77	91.3	14.70	1 to 3	180 to 250
CX-3	53.51	16.0	25.33			5.16	85.0	13.55	4 to 5	225 to 325
CX-4	75.10	10.0	9.38			5.52	90.0	14.50	2 to 3	250
CX-5	70.41	20.0	4.69			4.90	85.0	13.25	1 to 2	360
CX-6	66.65	11.0	16.88			5.47	89.4	14.15	1 to 4	285
CX-7	65.72	25.0	4.69			4.59	84.3	13.10	1 to 2	330
CX-8	90.30	3.5	0.30			5.90	92.5	15.10	2 to 3	200
Tungsten-Cobalt-Titanium										
CY-1	78.39	9.0		6.00		6.61	90.5	12.60	3	220
CY-2	78.86	6.0		8.00		7.14	92.0	12.85	1 to 2	207
CY-3	76.98	10.0		6.40		6.62	90.5	12.55	4 to 3	175 to 250
CY-4	77.92	13.0		3.20		5.88	89.5	14.10	1 to 4	310
CY-5	76.98	8.0		8.00		7.02	91.5	12.00	3	190 to 225
CY-6	75.10	8.0		9.60		7.30	91.8	11.75	1 to 2	200
CY-7	71.35	8.0		12.80		7.85	91.5	11.15	4 to 3	140 to 210
CY-8	75.10	4.0		12.80		8.10	92.0	11.00	2	120
CY-9	64.31	6.5		19.99		9.20	92.0	9.80	3 to 4	180
CY-10	57.27	7.0		25.59		10.14	92.5	9.10	3	100 to 200
CY-11	81.68	9.0		3.20		6.12	90.8	13.35	1	220
CY-12	75.10	10.0		8.00		6.90	90.8	12.15	1 to 2	250
Tungsten-Cobalt-Tantalum-Titanium										
CZ-1	79.30	10.0	0.94	3.20		6.06	90.5	13.35	3 to 4	190 to 300
CZ-2	71.35	8.0	3.75	9.60		7.30	92.0	11.80	3 to 4	165 to 225
CZ-3	70.41	8.0	4.69	9.60		7.30	91.5	11.80	2 to 3	165 to 225
CZ-4	68.06	9.5	7.50	8.00		6.94	91.0	12.00	3	250
CZ-5	47.38	7.0	9.38	25.59		10.15	92.7	9.00	2 to 3	100
CZ-6	87.31	3.0	3.61	0.12		5.96	92.2	15.10	1 to 3	150 to 250

*In listing the chemistry of the various grades, suppliers have preferred to show percentages of the various elements in their metallic form, even though they occur as carbides. Carbon percentage, therefore, is calculated by subtraction of the total metallic content from 100%.

†May be expected to vary ± 0.3 unit.
‡May be expected to vary ± 0.15 g. per cc.
§Broad range only; figure varies considerably with variations in test procedure.

Table III – Summary of Typical Applications for Sintered Carbides

Carbide Grade	Comments
	Tungsten-Cobalt
CQ-1	Roughing cuts on cast iron and nonferrous materials. Relatively coarse grain (No. 3) gives greater toughness at slightly reduced hardness; good for wear applications.
CQ-2	General-purpose machining of cast iron, nonferrous materials and stainless steels. Finer grain than CQ-1, greater wear resistance.
CQ-3	Light finishing cuts on cast iron and nonferrous materials. Higher hardness and wear resistance give longer tool life.
CQ-4	Precision boring of cast iron and nonferrous materials. Highest hardness and wear resistance of the CQ series.
CQ-5	For use on cast iron where high toughness is required; also for wear applications.
CQ-6	High cobalt imparts good toughness. Primarily for wear applications such as gages and blades for work rests of centerless grinders.
CQ-7	Similar to CQ-5, except for coarser grain which provides better toughness. Mostly for wear applications with little or no shock.
CQ-8	For wear applications with heavy shock.
CQ-9	High cobalt gives good toughness for most uses involving severe impact.
CQ-10	For wear surfaces subject to heavy shock or moderate impact.
CQ-11	Similar to CQ-6, but larger grain size; mainly for wear where shock is involved.
CQ-12	Roughing cuts on cast iron and nonferrous materials. Slightly tougher than CQ-1.
CQ-13	Similar to CQ-10 and CQ-6 but tougher.
CQ-14	For wear applications with medium to heavy shock or light impact.
CQ-15	Impact grade for moderate to heavy duty.
	Tungsten-Cobalt-Tantalum-Columbium
CU-1	For heavy cuts on alloy or plain cast iron using planers, boring mills and large lathes; also on steel where speeds are low and for heavy cuts on austenitic stainless steels.
CU-2	For roughing and moderate cuts on cast iron and nonferrous materials. Similar to CQ-1 and CQ-2.
CU-3	For die applications requiring heavy impact resistance — heavy blanking punches, cold heading dies and nibbling dies.
CU-4	For dies in medium to heavy impact service — crushing hammers and rivet sets.
CU-5	For dies where moderate impact is involved — lamination dies and punches, heavy forming dies and heading machine hammers.
	Tungsten-Cobalt-Tantalum-Titanium-Columbium
CW-1	For continuous or interrupted roughing cuts on carbon and alloy steel forgings, bar stock and tubing, of 0.30% C or above, free from sand or scale.
CW-2	Crater-resistant grade for moderate cuts on steel of 0.30% C or above, or for heavier cuts on lower carbon steels, particularly where high surface speeds and mechanically held inserts are used.
CW-3	Good crater and edge wear-resistance. Used where edge wear due to light chip load on steel is encountered — form tools, tools of large nose radius or where tools must dwell at end of cut.
CW-4	For precision finishing of steel, has high hardness and excellent cratering resistance.
	Tungsten-Cobalt-Tantalum-Titanium-Columbium
CW-5	For use where high strength and abrasion resistance are needed, as for roughing steel castings or scaled forgings. Good for interrupted cutting with light chip load.
	Tungsten-Cobalt-Tantalum
CX-1	General-purpose machining of cast iron and nonferrous materials. Similar to CQ-1 but with increased toughness.
CX-2	Special cast iron cutting grade, for use on alloy iron where greater wear resistance than CQ-2 is desired.
CX-3	Special die grade with good thermal shock properties for high-temperature applications — cutting hot flash from welded tubing, and in hot pressing operations.
CX-4	For roughing cuts on steel, particularly when a heavy cut at slower than normal speed is involved.
CX-5	For medium to heavy impact service.
CX-6	Roughing cuts on steel; good toughness and fair wear properties.
CX-7	High cobalt imparts excellent toughness for most severe impact applications.
CX-8	For fine finishing cuts on cast iron and light cuts on nonferrous materials; also good abrasion resistance.
	Tungsten-Titanium-Cobalt
CY-1	For roughing cuts on steel.
CY-2	For light finishing cuts on steel.
CY-3	General-purpose machining of steel. Higher cobalt and mixed grain size give greater toughness than in CY-1, CY-2 and CY-4.
CY-4	Die grade for wear applications with heavy shock; also for impact service.
CY-5	General-purpose machining of steel where higher hardness and wear resistance are desired.
CY-6	Finishing cuts on steel; good resistance to abrasion and cratering.
CY-7	Light finishing cuts on steel.
CY-8	Precision boring of steel; high hardness and wear resistance with low toughness.
CY-9	Precision boring of steel; more wear-resistant than CY-8, less than CY-10.
CY-10	High wear resistance, good for precision boring. Difficult to grind.
CY-11	Roughing cuts on steel; good toughness due to low titanium.
CY-12	Steel-cutting grade for roughing and general-purpose usage.
	Tungsten-Cobalt-Tantalum-Titanium
CZ-1	Roughing cuts on steel. Tantalum increases toughness without lowering cratering resistance.
CZ-2	Light finishing cuts on steel. Good toughness and wear resistance.
CZ-3	Similar to CZ-2, but slightly less wear-resistant with increased toughness.
CZ-4	General-purpose machining of steel. Similar to CY-5 but with greater toughness.
CZ-5	Precision boring applications. High titanium and tantalum provide excellent wear properties but make grinding difficult.
CZ-6	Light finishing cuts on cast iron and nonferrous materials. Similar to CQ-3 but with greater wear resistance and lower toughness.

Basis of Tests for Standardization

water, at room temperature for 3 to 4 min. Electroleaching is done in a 2% by weight solution of ammonium chloride; the specimen is made the anode, using an anode-cathode voltage of 1 to 2 volts for 30 to 60 sec. The electroleached structure is examined at 1500 ×, with observations being made for cobalt distribution, size of cobalt areas, discontinuity of cobalt grain boundaries and bonding of the carbide grains.

Hardness of sintered carbides is measured by the Rockwell tester, using the "A" scale, with 60-kg. load and a diamond brale indenter. A surface finish on the specimen equivalent to that produced with a 220-grit diamond wheel is recommended. Because of the shallow penetration of the diamond indenter, the surface under test must be parallel with the supporting anvil; if only slightly out of parallel, the hardness reading is inaccurate. Another precaution is to locate the testing machine free of vibration, as by mounting it on a heavy iron plate supported on springs or a rubber block.

The original classification listings gave chemical analysis on the basis of metallic carbide content, rather than by individual elements. However, at the suggestion of a number of suppliers, they were revised to show all analyses by percentages of each separate element, with total calculated carbon shown by itself.

Analyses in the tabulation are considered nominal. Specific gravity may vary plus or minus 0.15 g. per cc., since it is dependent to some extent on porosity and the variation in shrinking during sintering. Hardness normally is expected to vary plus or minus 0.3 point. Transverse rupture strength values are given as broad ranges and are for information only, since variations in testing procedure make direct comparisons of these values difficult.

RELATION TO USE

As to applications, shown in detail in Table III, it may be said in general that the tungsten carbide plus cobalt grades have good hardness and wear resistance, suiting them to machining cast iron and nonferrous materials and for wearing parts requiring toughness. These grades, however, lack crater resistance and tend to wear away rapidly under the action of a steel chip. Titanium carbide and, to a lesser extent, tantalum carbide provide crater resistance, and all steel-cutting grades contain either one or both of these carbides.

Development of the carbide classification system, while marking substantial progress on a long-term investigation, is but one phase of Buick's over-all tool program. It is under continuous scrutiny by a tool committee formed shortly after World War II. Serving on the committee are representatives of the following departments: master mechanic, standards, purchasing, inspection, tool research, tool manufacturing, tool grinding and metallurgical. Their objectives may be summarized as follows:

1. To make investigations of all tool materials.
2. To improve the general quality of tools and tool materials in order to reduce manufacturing costs.
3. To focus attention on known causes of tool failures.
4. To institute a better quality check on commercial tools.

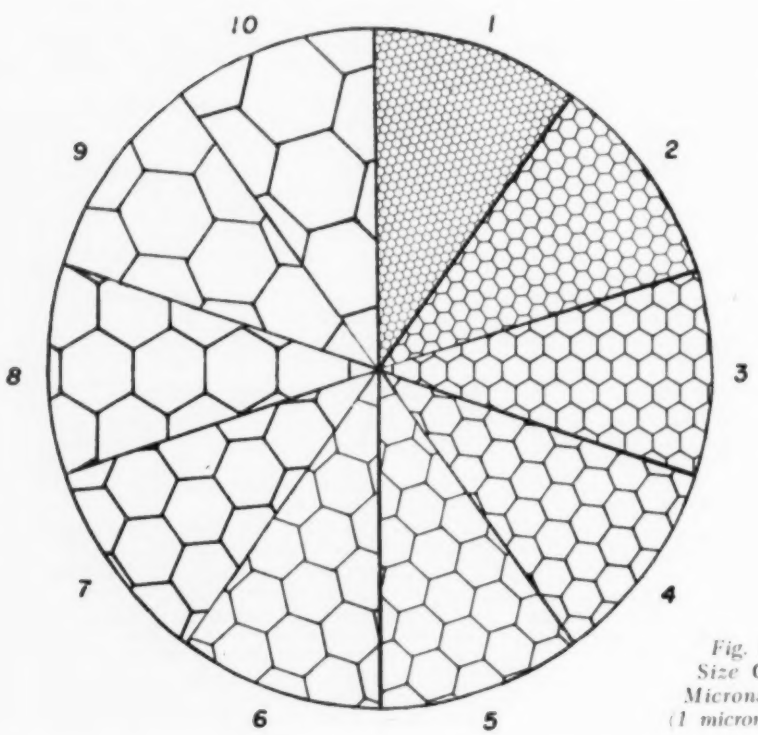


Fig. 5 – Carbide Grain Size Chart for 1 to 10 Microns, at 1500 Diam. (1 micron = 0.00003937 in.)

5. To investigate causes of tool failures and, where possible, to recommend corrective changes.

6. To investigate the value of more complete tool records on specific jobs.

7. To investigate tool sources in an effort to determine their ability to furnish tools of uniform quality.

8. Whenever Buick manufactures, reworks or sharpens tools, to see that such work is of the highest quality.

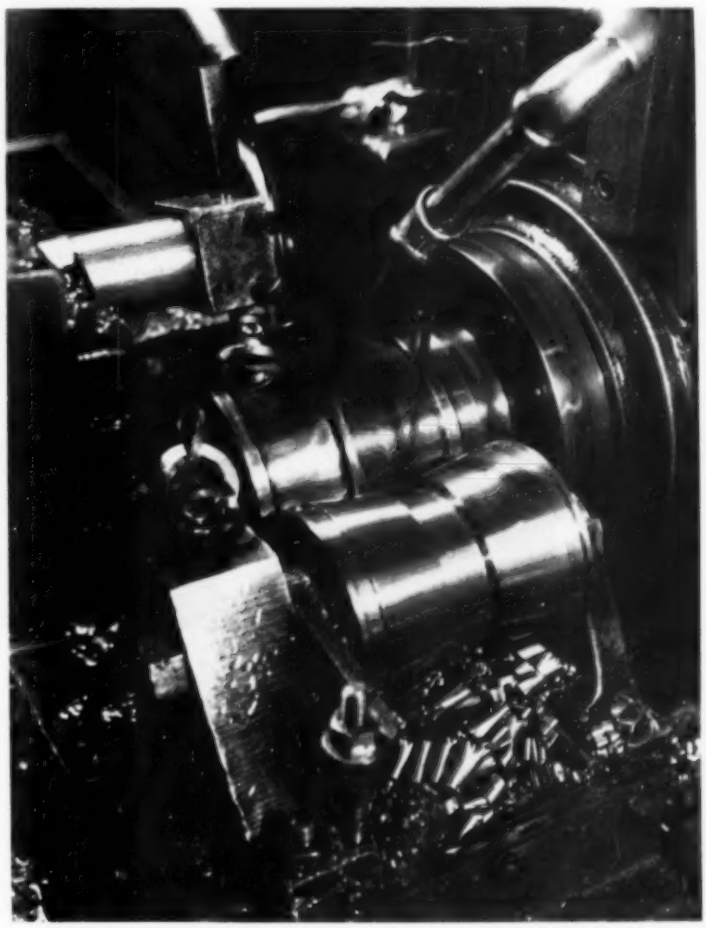
9. To institute an educational program on tool materials for production supervisors and workmen, aimed at the proper care and use of tools in the plant.

With the formation of this committee, more than 500 years of tooling experience were pooled in a cooperative effort to obtain maximum tool efficiency. When the committee was organized, rejections of toolsteels were running about 5%, as inspected against General Motors standards. By continuous effort and work with sources, the rate of rejections has been reduced to less than 1%.

Another important phase of the committee's work was a carbide training program, carried out for 320 plant supervisors and covering six lecture sessions of one hour each. It was received enthusiastically and attendance was near perfect. As an outgrowth of this project, a Buick Tool Manual was published for distribution to all who attended the training program sessions and to other members of management who were interested in tooling.

As a final step in enlisting the cooperation of machine operators, a brief tooling instruction card was distributed among them. These cards served as a means of contact between foremen and men on the machines, as well as a continuous reminder of the importance of proper handling and use of carbide tools. They are supplemented by posters, placed at 75 strategic locations throughout the plants and changed twice a month. The program naturally is a continuing one. Still better quality standards for carbides are in process of refinement. Suitable quality tests for abrasives are under development. New techniques for grinding carbide tools, minimizing and even eliminating the need for diamond wheels, are being studied and are close to the production stage.

Shop tests for the application of carbides are most essential, for the performance of the carbide is so dependent upon the conditions of use. The same applies, of course, to other tools, but because of the high hardness of the carbide its susceptibility to breakage makes tests under operating conditions highly important. Further, an acceptance inspection system on incoming shipments of carbides has been a basic element in the tool control program at Buick for a number of years.



Courtesy Timken Roller Bearing Co.

Biographies of

Eminent Living Metallurgists

Stanton Umbreit

Expert in Electronics

For most of his adult life Stanton Umbreit has been striving to improve the performance and manufacture of radio tubes and other electronic devices, and as a consequence he has become something of an expert, although you would never suspect it from his modest and reluctant account of himself. For the past 23 years he has headed up the metallurgical end of RCA Victor's development work on receiving and transmitting tubes for radio and television, and the programs from all over the world that reach you in your living-room may well have come about partly as a result of his labors.

Unfortunately for the fame of a scientist like Stanton Umbreit, the work that he has devoted his life to is so specialized and recondite that almost nobody except his boss and members of Committee B-4 of the American Society for Testing Materials can appreciate what he's up to. Certainly, in a day when the lay public has come to judge a scientist by the size of the galaxies he has discovered or by the vast devastation of the atomic explosion he can control, a man who has devoted his skill to the interior of a small vacuum tube – a mere cubic inch or so of space – seems likely to remain almost anonymous.

Umbreit belongs, therefore, in that small army of solid and often brilliant men whose quiet and unceasing work in many fields has made American industrial methods and products the whizzes that they are.

Stanton Umbreit's grandfather left Saxony about a hundred years ago to keep from being "unified" by Bismarck, and settled in Milwaukee. His mother's family, the Stantons, came here from England in 1635. Stanton himself is an interesting mixture of Wisconsin-German and old New England stock. Tall, rangy, sandy-haired, he actually could pass for a State of Maine farmer.

He was born in Milwaukee in 1895, where his father was a lawyer, and eventually entered the University of Wisconsin with the idea of becoming a civil engineer. Had he carried out that plan it would have been a serious blunder for society, for certain aspects of the science of metallurgy might have become far less advanced. Fortunately, chemistry and physics appealed to him more than surveying and bridge design, and he took his degree in chemistry in 1916.

Umbreit's first job was with the Newport Chemical Co. doing development work in dyestuffs – which World War I and the cutting off of the German imports had made very scarce – as well as dye intermediates, phenols, and explosives. After a year of this he returned to the University of Wisconsin where he put in a year of graduate work and taught classes in chemical engineering and metallography.

In 1918, he went with the National Lamp Co. at Nela Park, Cleveland (now the G. E. lamp department), at first as a chemist, later as a metallurgist in the development work on tungsten and also on Dumet, a copper-sheathed wire with an iron-nickel core that is now embedded in the glass base of all lamps and tubes. Dumet's chief virtue is that it will expand and contract at the same rate as the glass it is surrounded by, thus protecting the inside of the tube from loss of vacuum or inert atmosphere, and the filament from oxidation. After five years of this, Umbreit left the National Lamp Co. and, in 1923, went with the Electron Relay Co. in Toledo, where he continued his engineering and development work on the metallic components of lamps.

In addition to his work on tungsten and Dumet, he developed a process for the reduction of thorium oxide to the metal thorium, which is an excellent source of electrons and a desirable addition to filaments. He not only experimented with tungsten-thorium compounds for filaments but also attempted to produce pure metallic thorium in wire form. Another of his developments was a tungsten filament containing boron nitrite. From 1925 to 1929 he did development work on radios, tube testers, and various power supply units for the Sterling Mfg. Co. in Cleveland.

Umbreit's career with RCA began in 1930 when he joined the staff of its radio tube division in the section concerned with the chemical, physical, and metallurgical development of radio receiving and transmitting tubes. In 1950 he was made manager of the chemical and physical laboratory at Harrison, N. J.

At RCA he has been chiefly interested in the metallurgical end of the work. He has worked particularly on nickel alloys and also developed the tungsten-molybdenum heaters used in RCA's tubes, as well as special cathode materials of nickel combined with special reducing agents – small amounts of carbon, silicon, and magnesium.

Throughout his career his work has been chiefly the solution of manufacturing problems and the development of new methods and materials. These industrial obligations now

leave him very little opportunity to carry out the details of new research himself.

Outside of his work at RCA, Umbreit continues to pursue his chosen subject in the work of the ASTM and is also active in the A.S.T.M., and on occasions has given talks before the A.I.M.E. and the American Ceramic Society, whose members are interested in his work on glass-to-metal seals. The introduction of metal receiving tubes in 1935 required the solution of new metallurgical problems that were peculiar to the tube industry.

It is interesting to learn just what such a man as Stanton Umbreit does to relax when he is at home with his small family at the end of a day's work. After a lifetime of living inside radio tubes all day long it might be supposed that his interests would have become inbred and that he would spend his evenings and weekends tinkering with the radio or TV, or thumbing through scientific journals. He does none of those things. Homecoming simply permits Stanton Umbreit to shift his strong imagination and curiosity to other targets.

In the first place he is an avid balletomane, and attends almost every performance of every ballet company that dances in New York. This means a 40-mile round trip from home in West Orange, N. J. Mrs. Umbreit usually goes with him. So does their daughter Carol, now 22, when she is home from studying horticulture at Pennsylvania State College.

Carol and her father used to do fancy ice skating on the frozen water hazard in front of the eighth green of the golf course near their home. Mrs. Umbreit, who was Ethel Jones of Columbus, Ohio, before they married in 1921, stayed strictly away from such cold revels. Nor will she join him at the fresh-water fishing he enjoys in New England and Canada. Her game with him is duplicate bridge, which they both play well. Another of his serious pleasures is amateur photography. He has picked probably the most difficult and exacting technique in that field – bromoil prints. The subjects of his camera are chiefly landscapes, taken on vacations in Maine and in Canada.

At heart, Umbreit is a New Englander, and in addition he has a great regard for the Gaspé country and for the city of Quebec. In fact, when somebody recently asked him the silly question, "What would you do if you had a million dollars?", he replied quite soberly that he would buy a house on Dufferin Terrace in Quebec and not stir out of it except to attend the ballet. ASTM

Considerations for Successful Use of Investment-Cast Type 410

THE MARTENSITIC stainless steels, Types 410 and 416 in particular, have proved to be extremely troublesome to investment founders and to consumers of these castings. The difficulty lies not in the structure beneath the surface – which in Type 410 is exceptionally clean and uniform for an investment cast steel – but in the surface pitting that is encountered to some degree by most, if not all, of the investment foundries which have tried to cast these alloys. Therefore, either the problem of control of pitting must be solved, to allow freer use of this alloy, or the designer must provide sufficient freedom in surface irregularities where the pits have no functional significance – that is, he must accept lightly pitted pieces. Machining to remove pits is the last alternative when the special characteristics of Type 410 and its related steels are desired.

By **DAVIDLEE VON LUDWIG**
Consultant, Brooklyn, N. Y.

For some years the author has considered this difficulty and has studied other characteristics of these metals. Tests made by W. W. Gilbert, University of Michigan, of the comparative machinability of samples cast by the

Difficulties From Surface Pitting

Arwood Precision Casting Co. confirmed empirical observations to the effect that the practical difference between the "free-machining" and "standard" martensitic, as well as austenitic, stainless steels is negligible. In fact, a high rate of tool wear was found with Type 416, which could more than offset any improvement in rate of removal of the metal. At best, machinability should be a tertiary consideration in choice of alloy for a correctly designed investment casting. The amount of metal to be removed should not normally constitute more than 2% of the casting bulk.

The surface smoothness of an investment casting is usually very important. Should smoothness have a functional significance, as in turbine bucket castings where erosion resistance demands an unpitted surface, or in food processing equipment and surgical instrument castings where hygienic standards demand smoothness, close standards are justified. Where, however, as often is the case, smoothness is expected for no reason other than esthetic, or because the machined counterpart had smooth surfaces imparted by the machine processes, it often happens that irregularities in the cast surfaces can and should be tolerated in the interests of practicality. Obviously, on parts subjected to dynamic stresses, notch sensitivity is a factor which must be considered. The pits which form in cast 410 stainless are not of such shape or magnitude as to constitute any appreciable threat to the fatigue resistance or the impact strength of investment castings. The pits are invariably shallow, well-rounded depressions formed during the complex reaction of surface oxidation.

The nozzle casting shown in Fig. 1 is between 2 and 2½ times normal size. The actual part is only 1⅛ in. long, has an inside diameter under ¾ in. and an outside diameter at the shoulder of about 1 in. If this casting were machined, the removal of only 0.010 in. or less of stock would completely remove all signs of the pits which were the cause of the rejection. In the normal application of investment castings the intent is to use all surfaces in the as-cast condition, machining only such functional details as may be necessary for bearing or other purposes requiring either a smooth surface or a tolerance closer than that which can be produced by the foundry.

This nozzle casting was used as-cast, except for an over-all smooth polishing operation to produce a shiny surface for easy cleaning. A single facing operation was performed to remove the irregularities in the gate area of the part. The pits shown in the reject rarely penetrate more than 0.005 in., but these cannot be removed by polishing without destroying the dimensions of the part.

Although many theories have been advanced, the cause of pitting is not known. The con-

Fig. 1 – Typical Surface Pitting of Type 410 Investment Castings. These are foundry rejects of nozzle for milk bottling machinery which did not meet the requirement for smoothness of cast surface

Effect of Variations in Chemistry

sensus is that some factor, as yet undetermined, is a variable which sensitizes the metal to pitting. A foundry may run for months without any difficulty from this condition, then encounter heats which are totally lost through heavy pitting. Careful analysis of the chemistry of the melts has failed to isolate any difference to which it can be attributed.

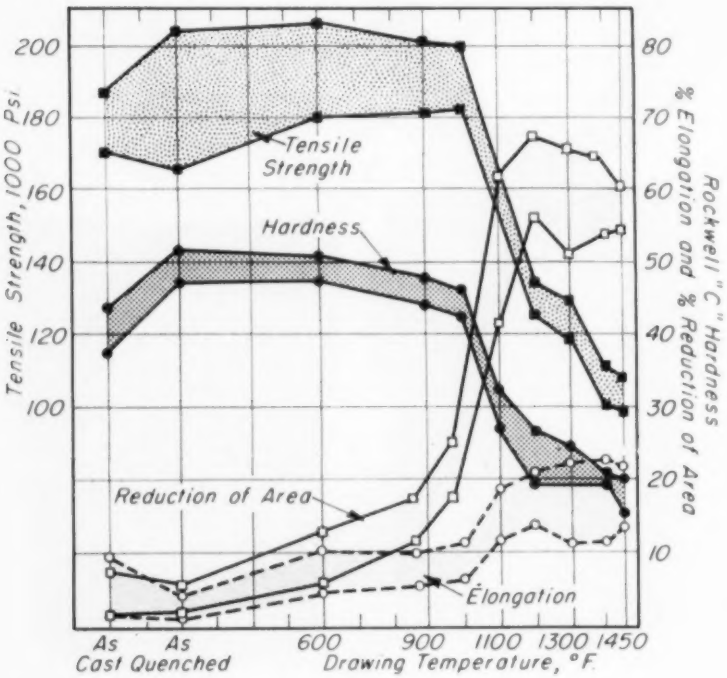
Consideration has been given to the possibility that the carbon level is the critical determinant. This possibility is enhanced by the fact that closely related alloys, such as Types 420 and 440, do not tend to form pits. Essentially, the difference in their alloy composition is in carbon content. Some relative balance between the carbon and the chromium is involved. When nickel is added to the alloy, pitting problems all but vanish. Of the austenitic stainless steels, pitting is encountered only in the modified grades, such as Types 321 and 347. These alloys pit only occasionally and only on very thin sections.

If it is assumed that the interrelationship between the carbon and the chromium is basic, there also remains the probability that variations in the chemistry associated with trace elements could be the key to these fluctuating difficulties with pitting.

An interesting further probability lies in the relatively poor and uncontrolled methods employed by many investment founders to dewax and fire their molds. The charging and heating methods often used with batch ovens are at total variance with the facts of thermal penetration of the charge. Furthermore, the usual designs of firing ovens do not provide for sufficient ventilation to insure thorough removal of moisture and the decomposition products of pattern residues. Consequently, a common result is that, within a given day, part of the run will be very clean and the balance will show heavy pitting. The ambient atmospheric variations may, of course, participate in this, but the difficulty has been encountered on days when barometric and humidity factors were found to be substantially stable.

In the course of performing some metallurgical studies for the completion of material for a book on investment casting ("Investment Castings for Engineers", Reinhold Publishing Co.), mechanical tests and metallographic studies were made of several hundred physical test bars cast from random production heats and a few controlled experimental heats of a number of different steels. Types 410, 420, 440, 302, 303 and 394 were among the stainless steels studied with various degrees of completeness. Because of the wide demand for 410, a fairly complete examination was made of this alloy.

Fig. 2 – Tentative Property Curves for Investment-Cast Type 410 Stainless Steel. High tensile strength and hardness are retained until after the metal has been tempered above 900° F.



From the tensile specimens of Type 410 cast for the study, random pieces were removed from the shoulder section of the test bar for the as-cast, quenched, and tempered conditions. These specimens were polished and etched with copper sulphate and hydrochloric acid. Examination was made at 2800× and at lower magnifications.

Both the micrographic study and the tensile and hardness examinations showed a high degree of uniformity in the properties of 410 stainless. Although other hardenable ferrous alloys, such as S.A.E. 4140 and 52100, were highly variable in their ductility, tensile strength and impact resistance, and were

comparatively sensitive to turbulence induced by variations in gating or pouring techniques, Type 410 was insensitive to these factors.

Where it was found that a high percentage, often 90% of a heat, of the S.A.E. alloys would fail due to grain boundary oxidation or inclusions formed as a result of turbulence in the metal poured in the investment molds, the loss of tensile specimens due to mechanical defects averaged under 7% for as-cast Type 410. It was quite interesting to observe that of the 7 to 10% of the specimens broken in the non-heat treated condition which had white oxide flakes at or near the surface, this form of defect totally disappeared after quenching and tempering, and only 5% of the specimens would fail due to inclusions or cracks.

The curves for the mechanical properties of Type 410 (Fig. 2) show a close correlation with the properties of this alloy in the heat treated condition for mill stock. The cast structure is somewhat harder and less ductile than the forged metal. The same retention of tensile strength and hardness which characterized the as-forged metal is evident in the high hardness level retained until the metal is tempered above 900° F. The same rapid softening and drop in tensile strength occur between 950 and 1100° F. for both conditions. Of the various steel alloys in the hardenable group, Type 410 had properties in the investment cast form which were most nearly identical with those in the forged condition.

The as-cast macro and microstructure of 410 is comparatively coarse. However, fine grain is not a measure of reliability or desirability of investment cast metal. Although S.A.E. 52100 is very fine grained and its grain size may be controllably modified by ladle inoculations with vanadium and post-casting heat treatments, it is one of the least uniform of all the ferrous alloys tested and definitely cannot be employed where dynamic loading or impact is to be expected. Heat treatment does not modify the macrostructure of Type 410.

As a result of the various examinations, the author believes that the potential which may be realized by proper foundry manipulation of the martensitic stainless alloys is sufficient to warrant further study of ways to overcome the problem of surface pitting. The tensile tests revealed that the existence of surface pits was no indication of defective base structure. Specimens cut from sprues and runners which were badly pitted and gassed yielded properties in line with those secured from bars removed from clusters which showed no signs of such condition. The high degree of internal cleanliness inherent with this metal indicates it may be incorporated in designs with considerable assurance. The potential mechanical properties are not as good as those which are theoretically possible with alloys such as S.A.E. 4140; however, the presence of turbulence-sensitivity in the latter throws suspicion on the use of alloys of this type, unless very careful inspection standards are established for stressed parts that are cast from them.

INVESTMENT TECHNIQUES REQUIRE STUDY

It is more than likely that some modification of the composition of Type 410 can be made which will retain the high degree of uniformity of basic properties, response to hardening and such, while suppressing or overcoming the matter of surface pitting. Another essential which must be considered is the correct firing of investment molds. Many metals, such as Type 302, form oxides which are retained as tough surface films on the casting surfaces and prohibit reactions from occurring, even though the investment molds may be loaded with steam and with decomposition gases from the plastic or wax patterns. It happens that Types 410 and 416 steels, as well as 321 and 347, are not as stable in this respect.

As to the choice of martensitic steel, preference is always given to 410 over 416. Type 416 is very undesirable in the foundry, due to the hazard of contamination of other metals with sulphur. Unless it is positively known that 416 is essential for an application, 410 should be used. If pitting is encountered and cannot be tolerated, Type 420 should be tried. It is more brittle, but with competent heat treatment adequate properties can be obtained for most purposes, provided the design engineer takes this substitution into account when laying out the part.

The basic understanding of investment casting metallography and metallurgy is still infantile to an extreme degree. Entirely new heat treatment methods must be devised before uniformly good results can be expected from many alloys which are being invested. I further believe that many standard alloys may require different standards and perhaps different compositions before they will produce reliable pieces by investment techniques. These phases have been overlooked in the natural desire for profitable applications.

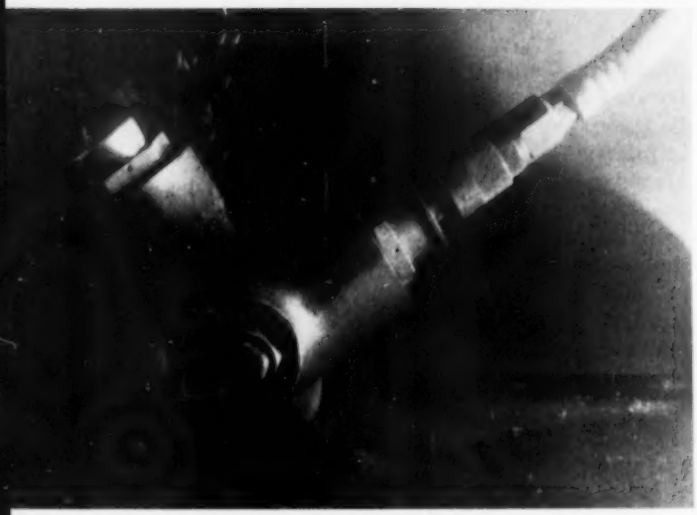


Fig. 1 – Porosity Is Revealed in Bronze Casting Intended for Pressure Service. Casting is connected to pneumatic line, all other openings are sealed, and it is then immersed in water. Air bubbles reveal areas of porosity

Correct Impregnation of Castings

ALTHOUGH porosity in metal castings has always been a problem to the foundryman, it has become more serious with the modern light metals, especially those castings bought under rigid specifications by airframe and aircraft engine manufacturers.

A casting containing microporosity is not necessarily structurally unsound. Microporosity, or its larger cousin, macroporosity, should not be confused with gross defects such as blowholes, sandholes, hot tears, pits, flaws, gas or shrink pockets. Microporosity is inherent in the physical fact that solid metal occupies less space than the same weight of liquid metal. While it is usually deep seated, or at least subsurface, it may appear on the shoulders of a casting where varying section thicknesses join (see Fig. 1). Such porosity also may appear where "sound" castings have been heavily machined to remove the "foundry skin".

By redesign of the part, by careful degasification of the liquid metal, by pouring at minimum temperatures, by proper location of gates and risers, and by other careful foundry techniques, the amount of porosity can be materially reduced. Likewise, some excellent alloys are much less susceptible than others widely used. However, even with the best of production techniques, which are usually costly and slow, a certain amount of porosity is all but inescapable. Porosity caused by gas absorption is especially bad, because this gas is released in the form of tiny bubbles while the metal is cooling, which work their way through the hot, plastic metal, leaving a passage and forming a type of connected porosity that nearly always results in leakage. In the light metals, particularly magnesium, microporosity is found along the crystalline grain boundaries. It is less apparent in fine-grained castings, and foundry techniques (and alloy compositions) should be directed with that objective.

By WILSON N. PRATT
Director of Research
American Metaseal Mfg. Corp., New York City

Leakage from pressure-tight systems is only one of the results of microporosity. Corrosion and failures in metal finishes are also a direct result. The author contends that many unsightly failures of applied finishes are caused by *internal* corrosion, and that effective impregnation of micropores will prevent them.

Impregnation of castings can ordinarily be done by three different methods, which are listed in military specification MIL-I-6869:

1. **Internal Pressure** – All openings in the casting are blocked except one. The impregnant is placed inside the casting and pressure is applied until it forces its way through the "connected" pores in the casting. (This type of impregnation is useful only to prevent leakage, and may overstress the casting.)

2. **External Pressure** – All openings in the casting are blocked except one connected to a vacuum pump. Reduced pressure inside the casting sucks the impregnant into the "through" pores. (This type of impregnation will only seal "through" porosity, and is extremely slow due to the small pressure differential.)

3. **Batch-Type Vacuum Pressure** – The castings, after thorough cleaning and dehydrating, are placed in a pressure vessel or autoclave.

A vacuum pump removes air from the autoclave, and any pore connected to the surface of the casting, whether it be continuous throughout the casting wall or not, will be evacuated. At this point, without breaking the vacuum, the impregnating material is introduced with compressed air; such pressure forces the impregnant into the evacuated pores. The casting is never under extreme stress, because the pressure, even if high, is equal both inside and out. At the end of the cycle, pressure is released, the castings are removed from the autoclave, and cleaned – particularly those surfaces that have been machined to fine tolerances to match, mate or slide against other surfaces. (Cleaning is particularly important in tapped holes; furthermore, if the part is to be finished by anodizing or plating, surface cleanliness is of extreme importance, since most impregnating materials are nonconductors.) After cleaning, a drying, baking, or curing operation solidifies the liquid impregnant which has been absorbed into the metal structure.

Prevents Leakage, Internal Corrosion, and Spotted or Blistered Finishes

IMPREGNATING MATERIALS

The first method used (for cast iron) was simple weathering, which produced enough iron oxide in areas of through porosity to block ordinary leakage. This effect was often automatically achieved during the aging necessary to produce a stress-relieved machine part. With the advent of artificial aging, rusting in the pores was also accelerated by filling the part with water to which various inorganic salts had been added, and applying pressure to force the solution out through the pores. The fastest rust-engendering material apparently was sal ammoniac (commercial ammonium chloride). This method is still used on some large ferrous castings that rust easily and are subject to low static pressures. When time is at a premium, the impregnant should leave solids of a different nature than rust in the pores. The favored material of this sort was sodium silicate, which, containing up to 60% water, was applied by internal pressure and sealed cast iron against those conditions for which rust was an effective sealant.

Such sodium silicate is an aquasol or hydrosol (a dispersion or suspension of submicroscopic droplets of sodium silicate in water) and is therefore subject to the "law of the passage of the least viscous liquid", and internal pressure results in a seal at the surface only. Consequently, various corrosive materials have been added to the sodium silicate suspension, intended to cause the inner connecting porosity to be "corroded shut". Also, because sodium silicate is excessively slow to work on macroporosity, it was found expedient to add various solids as well – usually metal oxides and sometimes fibrous materials such as ground asbestos. These materials produce effective surface seals. However, a corrosive agent in sodium silicate may produce dangerous corrosion products which exude from the pores to the surface, and cause subsequent trouble due to their hygroscopic, abrasive and corrosive properties.

Because of the many shortcomings of these impregnants and leak-stopping methods, many natural or synthetic oils and resins or mixtures thereof were tried; some are still in use. Tung oil, a drying oil often used in paint formulation, was found to be effective in stopping leakage due to microporosity of the type found in magnesium castings. To improve penetration the viscosity of the tung oil was lowered by additions of compatible materials such as xylol or other benzene derivatives. Xylol does not enter into the polymerizing action and escapes as a gas, either before or during the curing treatment.

Although tung oil was the best impregnant known at the time for microporosity, it was completely ineffective to seal macroporosity.

Polyester-Type Impregnants

Synthetic resins such as the phenolics were tried next on aluminum or stainless steel. These resins are extremely corrosion resistant, but can be used only in solutions containing as much as 50% of solvents such as acetone or alcohol, which, again, do not enter into the polymerizing reaction and must be driven off before or during the curing treatment. Also, the phenolic polymerizing reaction is of the so-called condensation type, which produces water vapor, and this must also escape.

Because neither drying oils nor the synthetic resins were effective impregnants for both fine and coarse porosity, the next developments were mixtures of both drying oils and resins. The styrene monomer can be made to co-polymerize with linseed oil or with dehydrated castor oil, producing a rubber-like solid that is suitable for sealing some castings against leakage. However, since large proportions of styrene are required to complete the reaction, it acts in effect as a solvent, and a good deal of it is volatilized while the penetrant is jelling.

Thus, all the above-mentioned impregnants, including sodium silicate, must be considered in connection with solvents which must be evolved or driven off during the drying or curing treatment. Paragraph 3 of military specification MIL-I-6869A states that the impregnant used in aluminum or magnesium castings should not be of a superficial type but should be capable of producing a solid, continuous structure throughout the porous section of the casting wall. U. S. Naval Engineering Experiment Station Report 4E(F2)101717 states that, as a result of work done on solvent-containing impregnants during World War II, "one of the important points demonstrated was that sealability of a compound was a function of the percentage volatile matter which passed off during the curing operation. It was shown clearly that compounds which were formulated with high volatile matter contents left a greater residual leakage after impregnation of a given pore size.... This behavior was attributed mainly to the opening of channels and expulsion of the solid matter during the release of solvent vapors in the baking process."

Their use demonstrated another important point: The solids which exuded from the pores of the castings during curing were extremely difficult to remove from the surface. Thus, castings impregnated with these materials were dirty, and frequently continued to leak! The organic material on the surface interfered with plating, anodizing and dichromating.

During the last war new types of synthetic resins were developed for molding products in which the reinforcing material was glass fibers. These resins, mixtures of polyesters and styrene, co-polymerize and form a thermosetting solid. Their outstanding feature is that there is no evolution of water vapor or other volatile matter; they are considered to be 100% solid, since there is practically no volume loss during polymerization.

However, they had several drawbacks: They had to be kept under refrigeration. Viscosity varied with temperature and effectively reduced their penetration into microporous sections. Also, traces of copper inhibited and halted the co-polymerizing reaction, and prevented their use on bronze, brass or other copper alloys and even excluded copper from all systems handling these resins. A further difficulty was in cleaning – solvents such as acetone or other ketones had to be used. Solutions were extremely sticky and difficult to handle. The

Table I – Comparative Properties of Impregnating Materials

Material	Per Cent Solids (Range)	Method of Application	Impregnating Ability	
			Microporosity	Macroporosity
Sal ammoniac in water	–	Internal pressure*	Fair	Poor
Sodium silicate	32 to 45	Internal pressure	Good	Poor
Sodium silicate with solids	35 to 50	Internal pressure	Fair	Good
Phenolics	50 to 75	Batch	Fair	Fair
Tung oils	40 to 70	Batch	Good	Poor
Styrene with linseed or dehydrated oils	50 to 70	Batch	Good	Poor
Modified flexible polyesters	90	Batch	Good	Poor
Styrene polyesters	94 to 97	Batch	Good	Good
Styrene polyesters, copper stabilized	94 to 97	Batch	Good	Good

*Cast iron only

washing of castings impregnated with the normal polyester styrene resins was an art performed on each individual casting, and was dangerous. Worst of all, the solvent tended to leach out the impregnant from the pores.

In spite of these practical difficulties, the inherent advantages of the polyester-type impregnant made it far superior to all previous types. It was a logical development to improve it and overcome these obstacles; in fact, within the past two years a new type of polyester impregnant has been developed which has effectively overcome the initial objections to the early polyesters.

A prime characteristic of this new material is that it will not jell at room temperature. It does not require refrigeration, agitation or aeration. The viscosity is maintained at the correct value and remains constant throughout the impregnation cycle.

A second basic development which represents a major improvement is an increase in the "wetness" of the new impregnant. This enables it to penetrate into the micropores; also it eliminates the necessity of volatile solvents such as acetone for subsequent cleaning.

Associated with these improvements are improved curing and cleaning methods. The new curing method employs hot oil and avoids the tendency for any residual free styrene to escape from the pores. The new cleaning method uses a non-ionic soap in an emulsion, resulting in a clean surface without solvent action.

Table I lists comparative properties and operating characteristics of all of the various types of impregnating materials and methods.

Using batch-type vacuum pressure systems and a modern polyester-type impregnant, all metals containing "connecting" porosity can be effectively impregnated. The first and most obvious result of such treatment is prevention

Results of Effective Impregnation

of leaks in pressure service. If the porosity is in such a form as to cause little or no distortion in the casting wall, a properly impregnated casting can be pressure tested to destruction without any leakage; many experimental magnesium and aluminum castings have been proof tested in this way. Bronze castings have also been successfully tested under hydraulic pressures as high as 6000 psi. without producing leaks in sections that were known to be microporous. Thus, if properly impregnated, an area that was formerly porous will withstand as much pressure as the sound casting. Of course, if the casting is thin-walled and is badly distorted during test, incipient porosity may be opened up under high pressure, but these sections will usually "close" as the pressure is reduced.

Corrosion Prevention – An equal, if not greater, benefit derived from proper impregnation with modern materials is the prevention of both chemical and electrolytic corrosion. Many studies have demonstrated that porous areas are extremely susceptible to electrolytic corrosion. Inclusions of foreign material generate electromotive forces in the presence of an electrolyte, sometimes destroying a casting internally without appreciably changing its surface. Electrolytic action will also enlarge and drive surface porosity deeper; it may completely penetrate the casting.

This is especially true of bronze and stainless steel castings, such as pump casings, in contact with corrosive liquids. Although such parts originally may not leak under hydraulic test, porosity which does not completely penetrate the wall can be detected with "Zyglo" or fluorescent inks. Proper impregnation effectively prevents the damage from spreading by

Exudation Characteristics	Stability in Metal	Cleanliness After Impregnation	Resistance to Metal Finishing Solutions	Resistance to Boiling Water and Steam	Chemical Resistance
None	Poor	Rusty castings	Fair	Poor	Poor
Exudes above 250° F.	Etches Al or Mg if used on both	Fair	Poor	Poor	Poor
Exudes above 250° F.	Etches Al or Mg if used on both	Good	Poor	Poor	Poor
Exudes badly	Good	Poor	Good	Good	Good
Exudes	Good	Poor	Good	Good	Fair
Exudes	Copper inhibits cure	Poor	Fair	Fair	Fair
Exudes	Copper inhibits cure	Poor	Good	Fair	Fair
Very little	Copper inhibits cure	Good	Good	Good	Good
None at all	Good	Good	Good	Good	Good

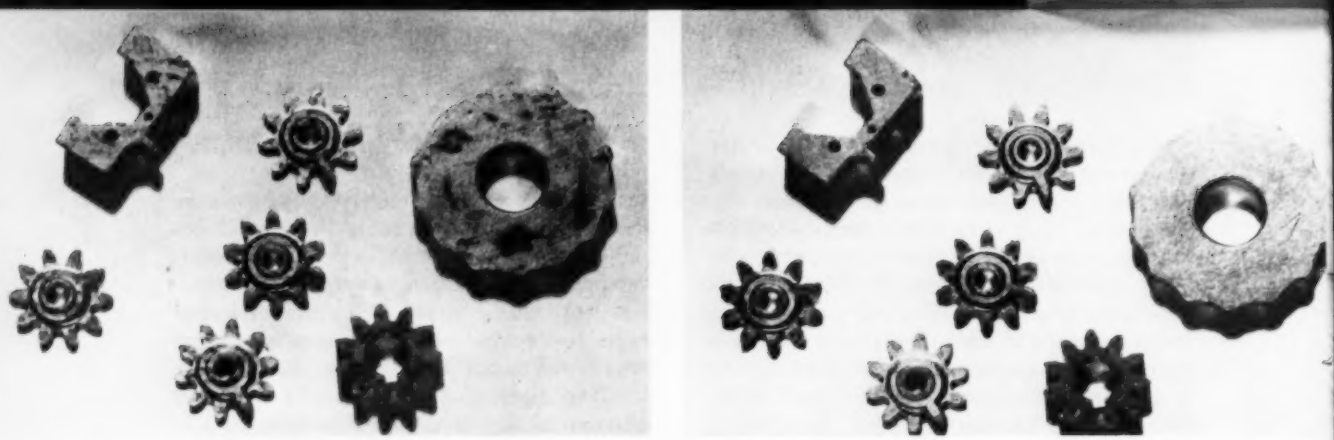


Fig. 2 – Pinion Gears and Other Sintered Iron Parts of Adding Machine, Cadmium Plated in Ordinary Manner, Show Exudation and Other Corrosive Effects After Ten Days' Test; the Cadmium Plate Has Completely Failed. At right the same parts which were sealed with polyester-type impregnant before plating show no evidence of corrosion or plate failure after five months' test

corrosion, as well as "fills up" the initial porosity. This greatly increases the normal life expectancy of such parts.

A related advantage is the protection of surface finishes. For example, if the anodizing solutions penetrate the walls of aluminum castings, gas will be generated in such pores, come to the surface and form a small bubble. This bubble effectively insulates the area; the bubble remains constant in size and sticks to the metal, preventing a small spot from becoming anodized. This shows up as a shiny bright spot if the parts are dyed black. To prevent "spotting" of anodized aluminum parts, they are often impregnated twice, before anodizing and dyeing, and again afterward to "fill" any further porosity which may have been opened up (or temporarily blocked off) by anodizing solution.

It is recommended that the impregnation of magnesium be performed after dichromate protection, so that all microporosity that is "smeared shut" during machining operations will be effectively filled. (See military specification MIL-I-7878, paragraph 3.3.3.)

Proper impregnation is particularly valuable in prevention of plating failures. Porous areas have a tendency to absorb plating and cleaning solutions; these exude and "spot out" after the plating cycle is complete. This problem is particularly serious in the powder metallurgy field. A manufacturer of adding machines which uses pinion gears of sintered iron found it impossible to cadmium plate the parts successfully. The original parts, shown at left in Fig. 2, were plated by approved methods, yet the parts were badly corroded after only ten days' exposure in test. If these same parts were impregnated before cadmium plating, they showed no evidence of corrosion after a five months' test, as shown at the right of Fig. 2. Impregnating before plating seals each pore with a dielectric material which not only prevents the platers' solutions from becoming entrapped, but does not allow an electrolytic "circle" to start in the pore.

In a similar manner, proper impregnation prevents failure of organic coatings on castings. Coats of paint will often blister during the baking or curing cycle because entrapped air in the pores underlying the paint film will expand. Obviously, filling the pores with a solid inert material will prevent this type of failure. Also, since no solvents or other free agents are present in the impregnant, it is quite compatible with all paints.

Such dangers from porosity, which may or may not extend through the casting wall, have been so effectively demonstrated that many parts which in service do not contain liquids or gases are impregnated on a routine basis. For example, aluminum brackets are often impregnated to cut down internal corrosion, even though the parts are anodized. Magnesium parts which are not intended for pressure service are often impregnated for the same reason; the metal in open pores does not have the same protection given to the surface by a treatment such as dichromating. When these porous areas absorb moisture as well as other contaminating materials, they corrode and may disintegrate internally with very little surface evidence. Proper sealing of porosity will prevent this deterioration.

Although many obstacles have been overcome in developing the new impregnating methods and materials, several additional improvements are on the way. It appears likely that impregnants resisting higher temperatures can be developed. Other studies are being directed toward even faster treatment cycles.

By C. G. A. ROSEN
Consulting Engineer
Caterpillar Tractor Co.
Peoria, Ill.

already in sight. The enormous growth of technological achievement in the 20th century has had two opposite effects on materials: It has greatly increased our efficiency of use, and it has also greatly increased the total drain upon our resources.

The demands which the materials problem places upon technology today seem roughly to be the following:

1. To foster new techniques of discovery.
2. To bring into the stream of use, materials which so far evade our efforts.

A Research Engineer Looks at Metallurgy*

CONFESSION is good for the soul. I am not a metallurgist. My introduction to metals was gained while standing on a box and swinging a sledge hammer in my father's blacksmith shop. In the late nineties I saw my first automobile and at that time I witnessed the repair of a fatigue-ruptured rear axle. The owner of the car had the choice of selecting a piece of Norway iron or a bar of toolsteel for a replacement shaft. The Norway iron was larger in diameter so the customer yielded to the philosophy of "big and soft". Strange though it may seem, down through the years this type of decision still frustrates agreements between engineers and metallurgists.

We have lived in a wonderful era – an age of scientific miracles. Our world is very old, yet only 400 years ago Magellan's crew circumnavigated the world in one year's time. In 1948 the globe was circled in three days and twenty hours. In my own time I have seen the great fleet of sailing clippers on the Embarcadero of San Francisco disappear, giving place to the giant steam-turbined ocean liner and the great diesel-motored freighter. Similar Aladdins have caused horse and buggy to yield to automobile, and captive balloon to airplane.

The last 100 years have been characterized by most intensive exploitation of natural resources. As engineering activities have accelerated, natural resources, food, fuels, minerals, have been used at an increasing rate. With many resources the bottom of the barrel is

3. To apply the principle of recycling more and more broadly.
4. To learn how to deal with low concentrations of useful materials.
5. To lessen or eliminate the need for a scarce material, as by substitution.
6. To develop and use more economically the resources which are renewable in nature.

As a nation we will undoubtedly remain in the deficit column of availability of many engineering materials. The aircraft industry, of necessity, has been committed to the saving of weight. The automotive industry – desiring to reduce drag, improve fuel consumption and offer more performance to the cash customer – has budgeted materials. Eventually *all* industry will be forced, by necessity, to use materials more efficiently through the combined efforts of good design and good metallurgy. Improvements of the future are more likely to come from a better understanding of how to use our present materials than from any sensational new wonder material yet to be discovered.

This leads me to the theme of my lecture, a plea for *closer cooperation between designers and metallurgists* in a conservation program.

In the past the work of mechanical engineers and metallurgists has always been related. However, they commonly work more or less independently – with numerous opportunities for "buck passing". Those industries under

*William Park Woodside Lecture for 1952 before the Detroit Chapter, ASM.

greatest pressure to use materials efficiently are combining the metallurgists and engineers into one group.

My good friend, Stan Sparrow, vice-president in charge of engineering of Studebaker Corp. – who would be here in my shoes tonight were it not for the tragic accident – wrote in *S.A.E. Journal* about a certain test program:

"Naturally, the connecting rods that failed were submitted to the laboratory for metallurgical examination. This is a very desirable procedure, since it provides a few hours for meditation between the time when the failure occurs and the time when the report comes back stating that the broken part is metallurgically perfect." Sparrow recognized that *both* the designer and the metallurgist play a part in any failure. Once this is recognized and understood, constructive action to have the two work together depends upon the urgency within a given industry for the most efficient use of materials.

In the automotive industry it would be well if we thought of designers as mechanical-metallurgical engineers. To a designer there should be no boundary between these two professions. This philosophy provides ample room for the metallurgist in his specialty, but makes the designer more conscious of the aims and aspirations of the metallurgist in solving common problems.

I can best illustrate these general principles by citing some specific situations in the development of diesel engines:

The major impediments to higher engine outputs, and increased ratings per pound of material, are the parts which form the combustion chamber envelope. The piston is one wall of a concentrated furnace box, subjected to excessive loads and temperatures. Under such stresses the structure supporting this firewall must reciprocate over lubricated surfaces, as well as form a pressure seal to imprison the energy-producing gases.

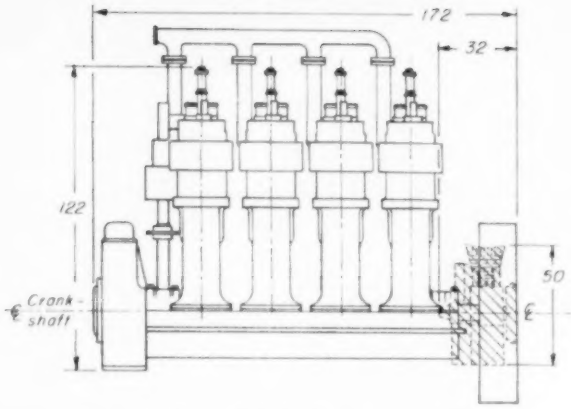


Fig. 1 – General Side Elevation of 200-Hp. Diesel of 1910, Contrasted With Hatched Diagram of 1948 Experimental Unit of Same Output. The old engine weighed 400 lb. per hp.; the new one weighs less than 2 lb. per hp.

The position which has been achieved by combustion research in the years of my experience is illustrated by Table I. The last column showing the brake horsepower per cu.in. of piston displacement indicates that the combustion process has been improved tenfold in 36 years. Even at that, we believe that horsepower output is not to be limited by combustion considerations. Durability at high specific output is the limiting factor.

This improvement (and economy) is more vividly illustrated by Fig. 1, where a comparison is made of a 1910 model rated at 200 hp. as against a single-cylinder unit developing that same amount in a 1948 version of the diesel engine. The 1910 model weighed 400 lb. per hp. whereas the experimental unit of 1948 weighed less than 2 lb. per hp. This is a clear tribute to the combined efforts of the chemist, physicist, engineer and metallurgist. However, commercial acceptability of units of higher ratings depends on the production of combustion chamber envelopes capable of enduring higher loads and higher temperatures. In each of the engines shown in Fig. 1 about 500,000 B.t.u. per hr. pass through the cylinder, cylinder head and piston; the 1910 model had over 40 times the heat-dissipating area. Such a difference in heat transfer surface is bound to exact a penalty on metals.

A better understanding of these problems can be had by reference to Fig. 2, a cross

Table I – Trends in Diesel Engine Designs

Model	Year	Horsepower*	R.P.M.	Piston Speed	Power per Cu. In.†
A	1910	50	250	750	0.098
V	1935	25	1000	1333	0.121
W	1943	45	1200	1600	0.213
X	1944	37.5	2000	2200	0.303
Y	1945	4.5	3600	1650	0.409
Z	1946	200	2000	2300	0.985

*Brake horsepower per cylinder
†Brake horsepower per cu.in. of piston displacement

section of a Caterpillar precombustion chamber diesel, with significant temperatures noted. The construction of the precombustion chamber is such that the highly atomized fuel is forced into a region where ignition takes place close to the end of the compression stroke. Ignition in the burner tube portion of the precombustion chamber establishes higher pressure than in the main combustion chamber, a differential of 100 to 200 psi. High speed Schlieren photography has indicated that peak velocities of the issuing stream from the burner tube may be as high as 1000 to 1200 ft. per sec. The fuel and air issuing from the orifice of the precombustion chamber into the main chamber reach maximum temperatures of 3800° F. Effective combustion is completed in 0.002 to 0.003 sec., and the cylinder is then scavenged of its inert and spent gases.

Higher ratings increase the temperature gradient considerably – as would be expected. Under such conditions the piston becomes a real metallurgical problem. There is need for heat resisting materials of high conductivity. Unfortunately, all our present ones have low conductivity. For instance, cast iron will withstand a much greater temperature than aluminum, but its poor conductivity causes it to run at a much higher temperature level than aluminum pistons. Aluminum will dissipate heat better, but its softening with age requires "crutches".

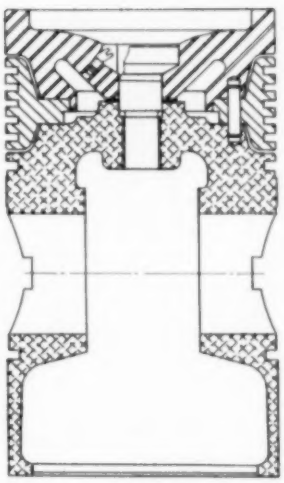
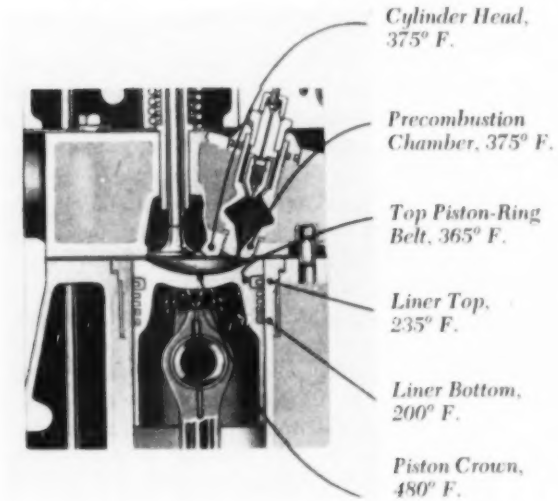


Fig. 3 – Sketch of Ideal (but not Commercial) Piston, With Heat Resistant Crown, Cast Iron Ring Belt and Aluminum Skirt

In Fig. 2 the top piston ring is shown guided in a cast-in ring groove of cast iron. By this single aid the piston lives four or five times longer than a single-piece aluminum piston. In supercharged engines the crown of the piston is sometimes fitted with a part looking something like a reversed exhaust valve – in reality a heat plug made of stainless steel; it takes the impact of the blast from the precombustion chamber. Such heat resisting heat plugs have extended the life of aluminum pistons three or four times.

If one were to construct an ideal piston, a structure similar to Fig. 3 would be obtained. This is a composite piston in which the crown facing the combustion chamber temperatures and pressures is of steel with suitable heat resisting properties. The ring belt is of cast iron to resist wear of the rings. The piston skirt is of aluminum for high conductivity. Thus, each part functions in relation to the services expected of it. Unfortunately, at present it would not be commercially practicable. A single-piece piston equivalent to this composite one would be very welcome to the diesel engine industry. This presents a challenge to the metallurgist. It is also a challenge for the engineer to cooperate, since he must design the entire engine so that the materials around the combustion chamber and behind the ring belt will dissipate heat rapidly and uniformly. The diesel piston remains the most critical element in retarding the full utilization of our advanced combustion knowledge.

Fig. 2 – Subsurface Temperatures at Various Places in Combustion Envelope of Diesel Engine of Moderate Mean Effective Pressure


Cylinder Head, 375° F.
Precombustion Chamber, 375° F.
Top Piston-Ring Belt, 365° F.
Liner Top, 235° F.
Liner Bottom, 200° F.
Piston Crown, 480° F.

CYLINDER AND LINER

Sharing almost equal responsibility for successful performance and long life of the engine is the cylinder or its liner. Heavy-duty engines usually have removable cylinder liners, frequently of induction hardened cast iron. Such parts require a high degree of uniformity in surface hardness and texture.

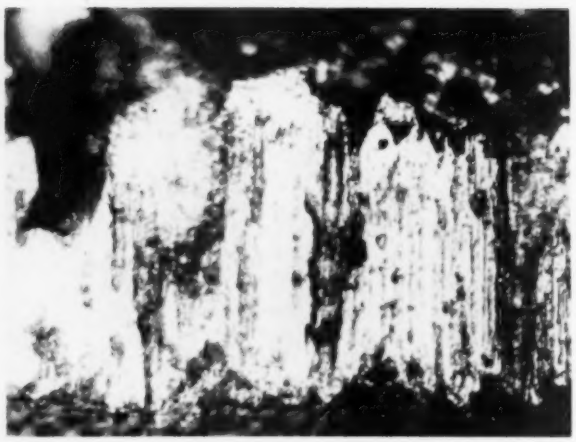


Fig. 4 (Left) – Photograph at 500 Magnifications of Normal Surface of a Piston Ring After Proper Machining. Fig. 5 (Above) – Heavy Surface Deterioration Near Top of Piston Ring After Break-In. Note that flow lines are at right angles to original direction (Fig. 4). 450 ×

After the liners have been honed and ground to the specified surface finish and dimension, they are treated by a caustic etching process, "surfiding", which removes deteriorated metal in those areas of highest hardening. Such partially fractured particles tend to accelerate mechanical abrasion by concentrating loading in local areas under the pressure of the piston rings. Etching also eliminates from the scene of break-in an extremely dangerous element often causing scuffing and scoring of the cylinders and rings.

A normally machined, satisfactory piston ring exhibits a surface at 500 magnifications as shown in Fig. 4, where there are indications of large metal particles arranged on the surface like small islands. Some of them appear to have been partially ruptured but not yet broken away from the surface. The weak, unsupported projections under load, either hydraulic or mechanical, are ready to be made to flow plastically. Compare such a raw, untreated surface with a surface after "break-in" or wearing-in, as shown at 450 diameters in Fig. 5. The orientation of the surface particles has been changed completely to right angles to their original distribution. Plastic flow has occurred; the micrograph shows the relatively large size of many particles of metal which have been removed along the top edge of the ring.

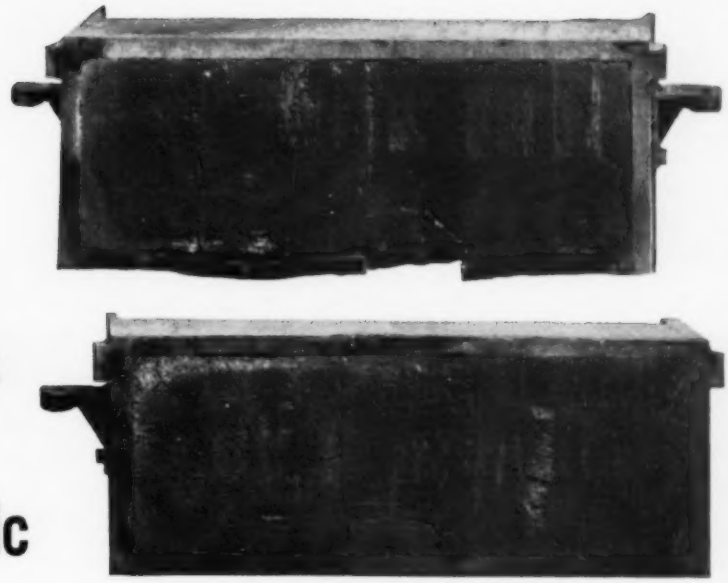
Consider now the action of such piston rings against a surfide-treated cylinder liner. Projections on the ring or particles removed therefrom will act as abraders coming in contact, under pressure, with the original surface of the liner (much as a plow in virgin ground), and displace metal without significant dimensional change. The shape of the abrader will determine the type of furrow produced and, unless scoring takes place, the metal in the path of the abrader must either yield elastically or be displaced laterally. If this displacement can take place without welding or without the tearing of material from the surface of the cylinder liner, wearing-in will be successful.

Flow of metal at the surface will largely be determined by the character and the distribution pattern of microcavities in close proximity. If there is no place for displaced metal to go, the forces are able to move the particle in line with the piston's motion, and no relief is available until a graphite "crater" is reached.

Modern cylinder irons of high wear resisting qualities have microstructures developed by experience in production and operation. Their graphite inclusions are inadequate to accommodate the displaced metal because the graphite is indiscriminately dispersed in random patterns, which do not guarantee the displacement of metal without injurious results. Even though the pits are comparatively close to each other, as shown in Fig. 6 at 250 × (p. 194), the spacing is nonunifo.m. Figure 7 shows a section of surfided cylinder liner after 100 hr. of engine operation. In the portion of the ring-travel occupied by the tracks of normal mechanical abrasion, the surfide coating is completely

(Continued on p. 194)

Ductile Iron Furnace Doors now used by General Electric



The Ductile Iron Door (lower photograph) is still good, as you can see, after three months of use on a steel forging furnace that operated with interior temperatures as high as 1950°F. After one week in same service, the gray cast iron door (upper photograph) is, obviously, ready for the junk heap.

Last 50 times longer...

At General Electric Company's River Works, West Lynn, Massachusetts, steel forging furnaces operate with interior temperatures as high as 1950°F.

Heretofore, gray cast iron door frames of these furnaces deteriorated from growth, warpage and scaling in about six days . . . and cost plenty in terms of down-time, replacement, and week-end overtime for repairs and maintenance.

Seeking a remedy, General Electric tried Ductile Iron door frames, cast by TAYLOR & FENN COMPANY, Windsor, Connecticut. And the result? Average life of these Ductile Iron doors is now estimated at about 300 days. Even though only seventeen furnaces reap this benefit, savings therefrom are estimated at $25,000 per year.

Ductile Iron provides oxidation and growth resistance to an extent heretofore unavailable in gray iron castings for furnaces, engines and other equipment subject to elevated temperatures.

High temperature applications of Ductile Iron castings include forging furnace door frames, sintering grate bars, pouring troughs, lifting plates for coil annealing machines, lifter bars in rolling mills, and scores of other parts subject to heat.

AVAILABILITY—Send us details of your prospective uses, so that we may suggest a source of supply from some 100 authorized foundries now producing Ductile Iron under patent licenses. Request a list of available publications on Ductile Iron . . . mail the coupon now.

The International Nickel Company, Inc.
Dept. 20, 67 Wall Street, New York 5, N. Y.

Please send me a list of publications on: DUCTILE IRON.

Name_____

Address_____

Company_____

Title_____

City_____

State_____

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N.Y.

Boron and Tentative Standard Steels

American Iron and Steel Institute, February 1953

Grade	Carbon	Manganese	Nickel	Chromium	Molybdenum	Notes
TS14B35	0.33/0.38	0.75/1.00	—	—	—	2, 4
TS14B50	0.48/0.53	0.75/1.00	—	—	—	5
14B52	0.47/0.55	1.20/1.55	—	—	—	5
TS4012	0.09/0.14	0.75/1.00	—	—	0.15/0.25	1
TS40B32	0.30/0.35	0.70/0.90	—	—	0.08/0.15	2, 4
TS40B37	0.35/0.40	0.70/0.90	—	—	0.08/0.15	3, 4
TS4130	0.28/0.33	0.45/0.65	—	0.90/1.20	0.08/0.15	1
TS4132	0.30/0.35	0.45/0.65	—	0.90/1.20	0.08/0.15	1
TS4135	0.33/0.38	0.75/1.00	—	0.90/1.20	0.08/0.15	1
TS4137	0.35/0.40	0.75/1.00	—	0.90/1.20	0.08/0.15	1
TS4140	0.38/0.43	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4142	0.40/0.45	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4145	0.43/0.48	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4147	0.45/0.50	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4150	0.48/0.53	0.80/1.05	—	0.90/1.20	0.08/0.15	1
IG42B35	0.32/0.39	0.70/1.00	—	0.40/0.65	0.08/0.15	1, 4, 9
IG42B40	0.37/0.45	0.70/1.00	—	0.40/0.65	0.08/0.15	1, 4, 9
IG42B45	0.42/0.50	0.70/1.00	—	0.40/0.65	0.08/0.15	1, 4, 9
IG42B50	0.47/0.55	0.70/1.00	—	0.40/0.65	0.08/0.15	1, 4, 9
TS43BV12	0.08/0.13	0.75/1.00	1.65/2.00	0.40/0.60	0.20/0.30	1, 4, 7, 8
TS43BV14	0.10/0.15	0.45/0.65	1.65/2.00	0.40/0.60	0.08/0.15	1, 4, 7
TS46B12	0.10/0.15	0.45/0.65	1.65/2.00	—	0.20/0.30	1, 4
TS4613	0.10/0.15	0.45/0.65	1.65/2.00	—	0.25/0.35	1
TS4618	0.15/0.20	0.45/0.65	1.65/2.00	—	0.25/0.35	1
TS4720	0.17/0.22	0.50/0.70	0.90/1.20	0.35/0.55	0.15/0.25	1
50B15	0.12/0.18	0.70/1.00	—	0.35/0.60	—	5
50B20	0.17/0.23	0.70/1.00	—	0.35/0.60	—	5
50B30	0.27/0.34	0.70/1.00	—	0.35/0.60	—	5
50B35	0.32/0.39	0.70/1.00	—	0.35/0.60	—	5
50B37	0.34/0.42	0.70/1.00	—	0.20/0.40	—	3, 4
50B40	0.37/0.45	0.70/1.00	—	0.35/0.60	—	5
50B44	0.42/0.50	0.70/1.00	—	0.35/0.60	—	5
TS50B46	0.43/0.50	0.75/1.00	—	0.20/0.35	—	5
50B49	0.47/0.55	0.70/1.00	—	0.20/0.40	—	5
TS50B50	0.48/0.53	0.75/1.00	—	0.40/0.60	—	5
TS50B60	0.55/0.65	0.75/1.00	—	0.40/0.60	—	5
TS51B60	0.55/0.65	0.75/1.00	—	0.70/0.90	—	5
80B15	0.12/0.18	0.60/0.90	0.20/0.40	0.15/0.35	0.08/0.15	5
80B17	0.14/0.20	0.60/0.90	0.20/0.40	0.15/0.35	0.08/0.15	5
80B20	0.17/0.23	0.60/0.90	0.20/0.40	0.15/0.35	0.08/0.15	5
80B25	0.21/0.28	0.60/0.90	0.20/0.40	0.15/0.35	0.08/0.15	5
80B30	0.27/0.34	0.55/0.80	0.20/0.40	0.15/0.35	0.08/0.15	5
80B35	0.32/0.39	0.65/0.95	0.20/0.40	0.15/0.35	0.08/0.15	5
TS80B37	0.35/0.40	0.75/1.00	0.20/0.40	0.20/0.35	0.08/0.15	3, 4
80B40	0.37/0.45	0.70/1.00	0.20/0.40	0.15/0.35	0.08/0.15	5
80B45	0.42/0.50	0.70/1.00	0.20/0.40	0.15/0.35	0.08/0.15	5
80B50	0.47/0.55	0.70/1.00	0.20/0.40	0.25/0.50	0.08/0.15	5
80B55	0.50/0.60	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
80B60	0.55/0.65	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
TS8115	0.13/0.18	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8117	0.15/0.20	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8120	0.18/0.23	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8122	0.20/0.25	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8123 (S)	0.20/0.25	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 6
TS8125	0.23/0.28	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8126 (S)	0.23/0.28	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 6
TS8127	0.25/0.30	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8128 (S)	0.25/0.30	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 6
TS8130	0.28/0.33	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8132	0.30/0.35	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8135	0.33/0.38	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 2
81B35	0.32/0.39	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
TS8137	0.35/0.40	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 3
TS8140	0.38/0.43	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS81B40	0.38/0.43	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	5
TS8142	0.40/0.45	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8145	0.43/0.48	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
81B45	0.42/0.50	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
TS8147	0.45/0.50	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8150	0.48/0.53	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	1
81B50	0.47/0.55	0.75/1.05	0.20/0.40	0.35/0.60	0.08/0.15	5
TS8155	0.51/0.58	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	1
TS8160	0.55/0.62	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	1
TS8165	0.60/0.70	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	1
TS8615	0.13/0.18	0.70/0.90	0.30/0.60	0.55/0.75	0.08/0.15	1
TS8617	0.15/0.20	0.70/0.90	0.30/0.60	0.55/0.75	0.08/0.15	1
TS8620	0.18/0.23	0.70/0.90	0.30/0.60	0.55/0.75	0.08/0.15	1
TS8622	0.20/0.25	0.70/0.90	0.30/0.60	0.55/0.75	0.08/0.15	1
TS8625	0.23/0.28	0.70/0.90	0.30/0.60	0.55/0.75	0.08/0.15	1
TS8627	0.25/0.30	0.70/0.90	0.30/0.60	0.55/0.75	0.08/0.15	1
TS8630	0.28/0.33	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8632	0.30/0.35	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8635	0.33/0.38	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8637	0.35/0.40	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8640	0.38/0.43	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8641 (S)	0.38/0.43	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1, 6
TS8642	0.40/0.45	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8645	0.43/0.48	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS86B45	0.43/0.48	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	5
TS8647	0.45/0.50	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8650	0.48/0.53	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8653	0.49/0.55	0.75/1.00	0.40/0.70	0.65/0.85	0.08/0.15	1
TS8655	0.50/0.60	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8660	0.55/0.65	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS94B15	0.13/0.18	0.75/1.00	0.30/0.60	0.30/0.50	0.08/0.15	5
TS94B17	0.15/0.20	0.75/1.00	0.30/0.60	0.30/0.50	0.08/0.15	5
TS94B20	0.17/0.22	0.75/1.00	0.30/0.60	0.30/0.50	0.08/0.15	5

NOTE 1 — An interim alternate (or tentative standard) steel designed to conserve nickel or molybdenum. They apply to hot rolled alloy steels generally not exceeding 200 sq.in. in cross-sectional area, or 18 in. in width, or 10,000 lb. in weight per piece. They also apply to alloy steel wire and to cold finished alloy steel bars.

NOTE 2 — For cold heading and cold forging wires, for making components up to and including ½ in. in diameter. A group of five grades is intended to provide material for a wide range of parts produced from alloy steel wire. For larger components, see NOTE 3.

NOTE 3 — For cold heading and cold forging wires, for making components over ½ in. in diameter and up to ¾ in. A group of four grades is intended to provide material for a wide range of parts produced from alloy steel wire. For smaller components see NOTE 2.

NOTE 4 — Designations with B are boron-treated steels, and can be expected to have 0.0005% min. boron content.

NOTE 5 — Boron-treated steels developed to conserve nickel and molybdenum, and can be expected to have 0.0005% min. boron content. Available as hot rolled alloy steels generally, alloy steel wire, and cold finished alloy steel bars.

NOTE 6 — Sulphur content of TS8123, 8126 and 8128 is 0.035 to 0.050; of TS8641 (S) is 0.040 to 0.060%.

NOTE 7 — Also contains 0.03% min. vanadium.

NOTE 8 — Silicon content is 0.20 to 0.40%.

NOTE 9 — IG represents an interim grade adopted in February 1953.

Notes on Composition

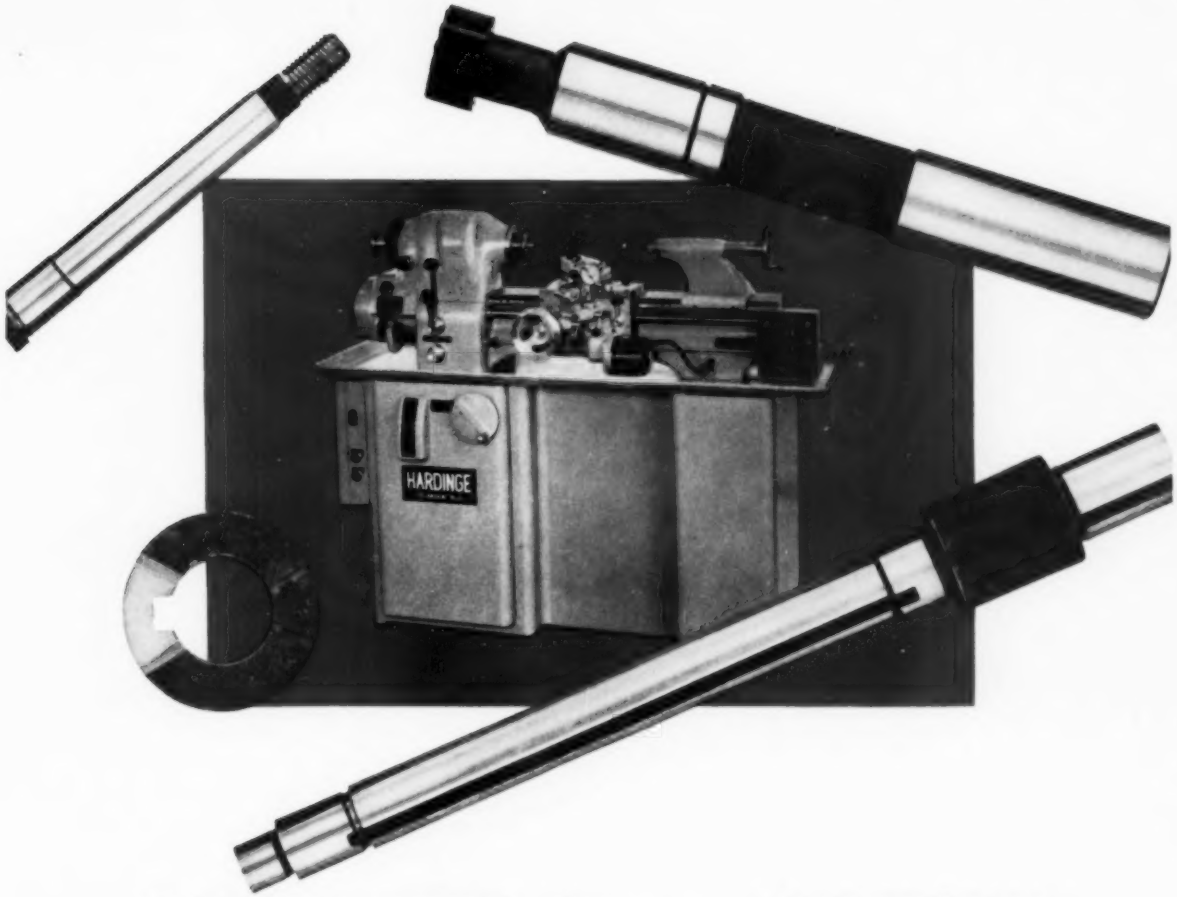
Phosphorus and sulphur limits for each process are:

Basic electric, 0.025% max.
Basic openhearth, 0.04% max.
Acid electric, 0.05% max.
Acid openhearth, 0.05% max.

An exception is TS8641 (S), whose sulphur is 0.040 to 0.060%.

Silicon range for each of the steels listed here is 0.20 to 0.35%, except TS43BV12 (0.20 to 0.40%). For acid openhearth or acid electric, minimum is 0.15%.

Incidental Elements — Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: Copper, 0.35%; nickel, 0.25%; chromium, 0.20%; and molybdenum, 0.06%.



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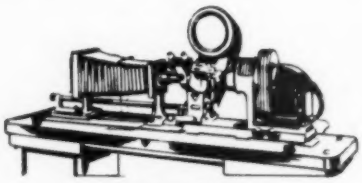

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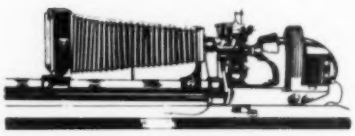

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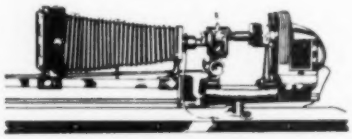

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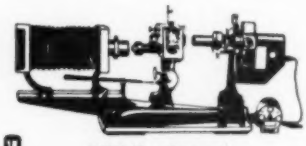

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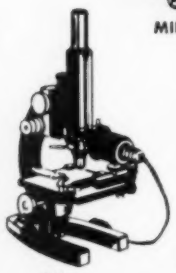
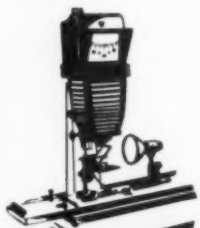


CM Metallurgical Microscope



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Bausch & Lomb *Metallurgical* Equipment

By R. L. CHENAULT, Chief Research Engineer, and G. E. MOHNKERN, Research Engineer
Oilwell Supply Division, U. S. Steel Corp., Oil City, Pa.

The authors wish to express appreciation to F. Lee Current and other members of the research staff for valuable assistance. C. W. Lindquist made the micro-examinations and hardness determinations, and W. L. Culbertson contributed much of his time to the long series of tests. They also wish to acknowledge the cooperation of the manufacturing department in adapting this nitriding process to commercial products. R. L. Stone has been very generous in assigning equipment for pilot runs that could not be made in the laboratory.

Pressure Nitriding for Hardening Internal or External Surfaces

SUBSURFACE pumps needed to raise oil from deep wells may operate at 10,000 ft. below the surface and even lower. The most popular size is a pump with 1½-in. bore, with wall thickness limited to ⅛ in. because it must be lowered within a 2-in. tubing. Pump plungers commonly vary from 3 to 6 ft. in length; plunger clearances of 0.002 to 0.003 in. on the diameter are common; pump barrels within which the plungers slide vary from about 4 ft. long to more than 30 ft. In action these parts are subject to abrasion of sand and the action of salty or other corrosive ground waters.

For such thin-walled tubular equipment the paramount requirements are reliability, expressed by a hard and uniformly thin case on the *inside* of the pump barrels, and the maximum amount of strong, tough core metal to withstand high operating stresses, exact dimensions and unusual straightness. Exacting dimensional requirements practically rule out any case hardening procedures which include quenching (warpage would be ruinous); a thin and uniform case indicates the desirability of honing to size before heat treatment. These specific needs, as so often in the history of the metal industry, were met by the development of an unconventional method we call "pressure nitriding". It will now be described since we believe it is applicable to many steel parts requiring high surface hardness, wear resistance, and accuracy of dimension.

Pressure Nitriding* – As is well known, conventional nitriding is done at 900 to 1050° F. in special closed furnaces through which ammonia is circulated at a few ounces of pressure above atmospheric, to prevent infiltration of air.

Pressure nitriding can be done in any heat treating furnace. The parts to be nitrided are placed in a closed container – in one practice, a pipe with welded ends – along with a capsule containing liquid ammonia; alternatively, the container is connected with a tank of gaseous ammonia under 200 to 800-lb. pressure. Furnace temperature of 1000° F. is satisfactory; time varies with the type of steel being nitrided and the desired characteristics of the case, but is usually somewhat less than when the job is done at slight pressure. Consumption of ammonia in pressure nitriding is but a small fraction of that required by conventional nitriding – on the order of 5% – due to causes to be explained in the sequel.

Pressure nitriding is therefore economical in reagent, in furnace investment, and in operat-

*The processes used in the high-pressure method for nitriding described in this paper are covered by U. S. patent No. 2,596,981 and additional U. S. and foreign applications.

Advantages of Pressure Nitriding

ing cost. It avoids the following disadvantages of the conventional method:

1. In the conventional method it is necessary to maintain a continuous, controlled circulation of ammonia gas during nitriding.

2. Furthermore, it is difficult to obtain a uniform rate of circulation through all parts of the furnace – a requisite for a uniform product.

3. Accurate controls of temperature, gas flow rate, and percentage decomposition of ammonia are required in the older conventional method. Ammonia decomposition is a function of the first two factors mentioned, and also changes as the nitriding progresses and affects the catalytic action of the steel surface. Therefore, close supervision is required to obtain the proper balance.

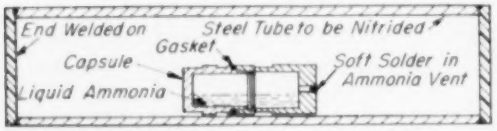
4. Ammonia is used in a very wasteful manner inasmuch as "spent" gases consisting of approximately 70% of undissociated ammonia are vented and a very large percentage of the nitrogen atoms liberated by the dissociation of ammonia will combine to form inert nitrogen molecules (N_2).

5. The special furnaces and control equipment required for conventional nitriding are expensive, and the initial investment is sufficient to discourage many potential users who might use it on a relatively small scale.

Operating Techniques – Figure 1 shows the arrangement we use for nitriding the inner surface of alloy steel tubes. The proper quantity of liquid ammonia is contained in a small steel capsule. The capsule is drilled with a small hole, and this is plugged by a low-melting solder. Inasmuch as liquid ammonia has a very high coefficient of expansion at high temperatures, a considerable space is needed in the capsule for expansion.

For filling the capsules, we utilize a refrigerator as shown in Fig. 2. The refrigerant is solid carbon dioxide in a bath of acetone to give good thermal contact with the coil conducting the ammonia from the supply tank. The soft steel capsules also are cooled in this

Fig. 1 – Sketch Showing Capsule of Liquid Ammonia in Closed Tube Ready for Nitriding Inner Surface of Latter



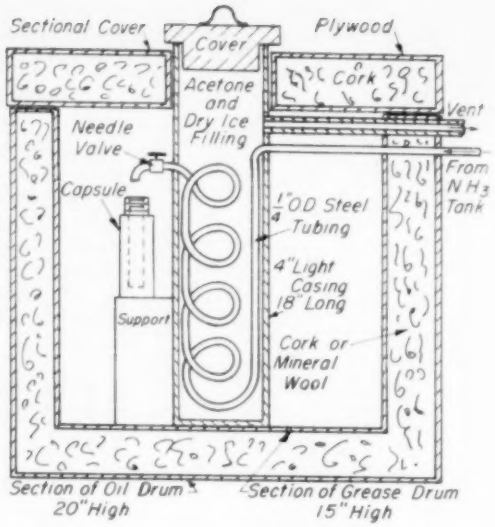


Fig. 2 – Cross Section of Home-Made Refrigerator for Loading Capsules With Liquid Ammonia

refrigerator to about —50° F., whereupon the liquid ammonia can be handled easily. After filling the lower part of the capsule, so proportioned that when it is full it contains the correct amount of ammonia for the intended job, it is clamped in a vise while the cap is screwed on and tightened onto a gasket to prevent leakage (Fig. 3). Ammonia at —50° F. does not evaporate fast enough to constitute a serious hazard during this short time before the capsule is closed.

The ammonia capsule is then placed into the steel tube and welded end plates or plugs close the tube. As the tubes are heated in the furnace, the soft solder melts and the liquid ammonia vaporizes and fills the tube to be nitrided. Under these circumstances we have

Fig. 3 – Operator Screws on Top of Capsule After Base Is Filled

Fig. 4 – Series of Closed Tubes Entering Conventional Tube Annealing Furnace

Fig. 5 – End Plugs on Nitrided Tubes Are Drilled in a Fixture, Internal Pressure Is Noted by an Inspector, and Ammonia Vented to the Outside

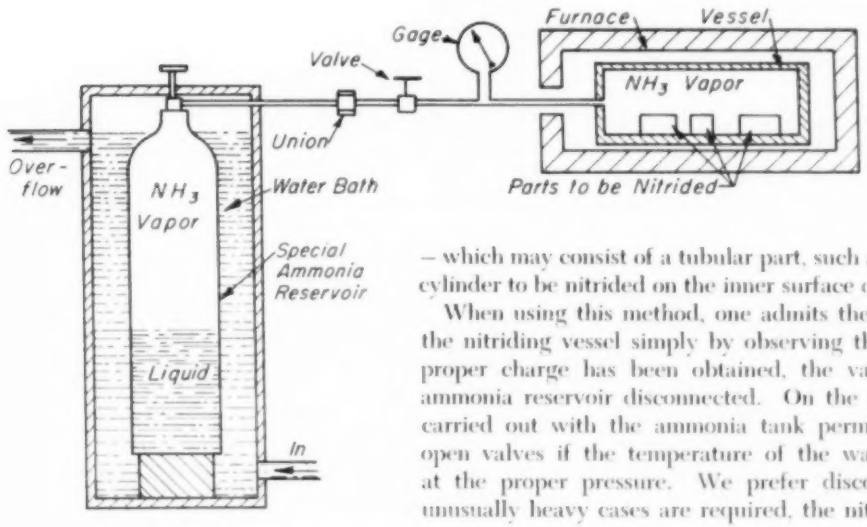
a completely isolated system for carrying out the nitriding operation so it is not necessary to have a special furnace or to connect the nitriding chamber to a source of ammonia. This is especially handy for hardening the inner surface of tubes where straightness is important. Such tubes can be rotated on level bearings or rolled through a furnace for nitriding (Fig. 4), and we find perfect straightness can be maintained under such conditions – that is, the tubes will come out as straight or straighter than when charged. It is also unnecessary at the low operating temperature to protect the outer surface of tubes that are to be nitrided only on their inside.

Figure 5 shows an end plug being drilled *after* nitriding. The pressure is checked immediately after the hole is drilled as a quality control expedient, and the valve immediately in front of the gage is then opened to vent the gas to the outside.

Other methods of releasing ammonia from the capsule, as a result of pressure, temperature, or mechanical manipulations, can be utilized, but the soft solder plug has proven entirely satisfactory. Obviously, a tube of proper size, closed at ends and containing an ammonia capsule, can be filled with smaller objects which require nitrided surfaces, thus acting as a closed retort or muffle.

Figure 6 sketches our method for nitriding where ammonia gas is admitted directly from a tank. This represents a thoroughly practical method which does not require metering of the liquid or vapor, inasmuch as the proper charge is obtained by controlling the pressure, which in turn is related to the temperature of the ammonia tank. The container is maintained at a controlled temperature by a surrounding water bath. The vessel containing parts to be nitrided is placed in a suitable furnace. Sometimes, it may be desirable to nitride in this manner the inner walls of the vessel – which may consist of a tubular part, such as a pump barrel or an engine cylinder to be nitrided on the inner surface only.

Fig. 6 – Sketch of Arrangement for Charging Nitriding Container With Ammonia Vapor From a Special Reservoir at Controlled Pressure



When using this method, one admits the proper quantity of vapor to the nitriding vessel simply by observing the pressure gage. When the proper charge has been obtained, the valve may be closed and the ammonia reservoir disconnected. On the other hand, nitriding can be carried out with the ammonia tank permanently connected and with open valves if the temperature of the water bath vaporizes ammonia at the proper pressure. We prefer disconnecting the source; where unusually heavy cases are required, the nitriding vessel may be vented,

Fundamental Reactions Involved

the tank reconnected, and the vessel recharged with fresh ammonia when desired.

We find that we can nitride very satisfactorily with ammonia charges giving pressures from 200 to 800 psi. at the heat treating temperature. If the ammonia tank is maintained at a temperature of 190° F., for example, the vapor pressure of liquid ammonia will be 709 psi. absolute, and this pressure will be maintained in the nitriding vessel when it is as hot as the liquid ammonia in the ammonia tank (190° F.) or hotter. In other words, the ammonia vapor in the nitriding container will be in a superheated condition with its pressure determined by the vapor pressure of the liquid in the ammonia tank. The simplest and safest procedure is to connect the apparatus when the container is slightly warmer than the water bath, open the valve and heat the container to 1000° F. before closing the valve. This will prevent an overcharge.

If the temperature of the nitriding container is below that of the ammonia tank during the filling process, it will fill with liquid ammonia and, of course, a dangerously high pressure will result if the shut-off valve is closed before the nitriding container is heated to operating temperature. A dangerously high pressure may also result from charging the nitriding container with ammonia vapor by maintaining the container at a temperature equal to, or above, that of the liquid ammonia tank but appreciably below final nitriding temperature.

Scientific Fundamentals – Comprehensive discussions of the nitriding action are available in the published literature – see especially the "Nitriding Symposium". The hot ammonia molecule in contact with metal (a catalyst) breaks down into its atoms, thus,

$$NH_3 \rightarrow N + 3\,H.$$

Atomic nitrogen is active chemically and combines with various metals at the surface of the alloy steel to form very hard nitrides. It also diffuses slowly as uncombined nitrogen or as nitride nitrogen into the subsurface layers. However, both nitrogen and hydrogen atoms combine into molecules quite rapidly:

$$2\,N \rightarrow N_2; \qquad 2\,H \rightarrow H_2$$

and these molecules are not nearly so reactive with metals and are so large that they cannot diffuse through the metallic space lattices. Thus, a large fraction of the ammonia which breaks into its constituents in a nitriding furnace rapidly becomes molecular nitrogen and molecular hydrogen, neither of which are of further use, but must be continuously vented from the furnace and replaced with fresh ammonia vapor.

However, the catalytic reaction becomes appreciably reversible at moderate pressures, thus

$$2\,NH_3 \rightleftarrows 2\,N + 3\,H_2^*$$

In other words, if the system is pressurized some of the nitrogen which does not promptly combine with the steel recombines with hydrogen to re-form some ammonia and will have another chance at the metal when this ammonia decomposes again. Stated in more scientific terms, the equilibrium between

$$NH_3,\ N,\ M_xN_y,\ N_2,\ H \text{ and } H_2$$

depends upon temperature and pressure, and as the latter is increased the amount of active N atoms increases in proportion both to the amount of ammonia and to the amount of nitrides (M_xN_y) already formed.

Our experiments with two alloy steels used for pump barrels and plungers, with ammonia pressure up to 2000 psi., indicate that 400 psi. is adequate for many purposes. While the rate of nitriding increases with pressure, there is little to be gained beyond 800 psi. except where unusually thick cases are required, and conditions make it desirable to use the capsule method of charging with ammonia. Temperatures of 1000° F. are also very satisfactory for cases of maximum hardness.

The relationship between temperature and vapor pressure of liquid ammonia is shown in the following table:

Temperature	Vapor Pressure (Absolute)
−28° F.†	14.7 psi.
100	220
125	310
150	430
175	570
200	790
225	1040
250	1350
271.4‡	1657‡

†Boiling point. ‡Critical points.

*This is the basic reaction of commercial nitrogen fixation processes utilized for the manufacture of ammonia. When nitrogen and hydrogen are mixed in proper proportions and heated under pressure with a suitable catalyst, part of the nitrogen and part of the hydrogen combine to form ammonia and the reaction comes to equilibrium after a definite percentage of ammonia is formed. Equilibrium depends on the pressure and temperature. The ammonia is removed by cooling and liquefying, while the nitrogen and hydrogen are sent back to the reaction chamber.

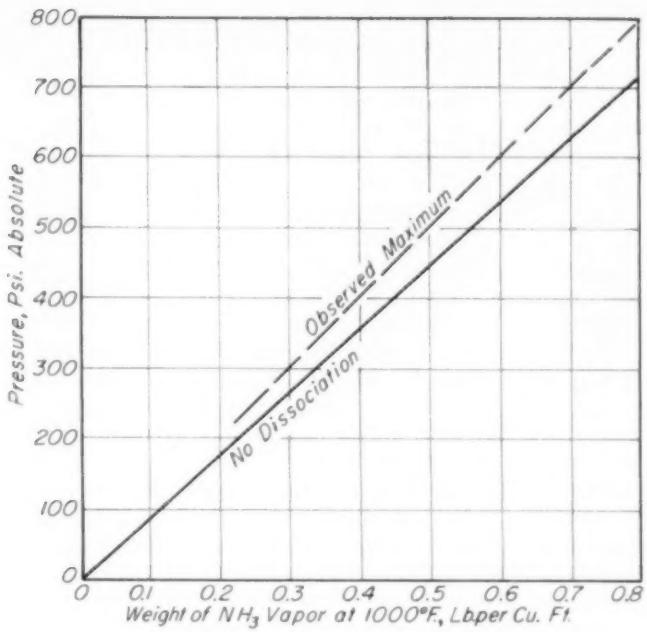


Fig. 7 – Weight per Cu.Ft. of NH_3 at 1000° F. and Various Pressures, Assuming no Dissociation. Dotted line represents observed maximum pressure in nitriding vessels for given theoretical densities

The practical range of 200 to 800 psi. can be obtained simply by heating the liquid ammonia reservoir to 100 to 200° F. in an open water bath. This also serves as a safety device to prevent serious overheating, as boiling water will give an ammonia pressure of only about 900 psi. Standard ammonia tanks are not designed to be safe at 900 psi., and therefore a special ammonia reservoir should be provided for use with the water bath, and this reservoir should be only half filled with liquid ammonia in the method of Fig. 6 to provide ample space for it at the boiling point of water.

Connecting tubing and fittings of Fig. 6 should be of small capacity to prevent accumulation of liquid ammonia in these fittings; they ordinarily are not warm enough to prevent ammonia vapor from condensing. However, the valve may be near the surface where its temperature will be higher than the ammonia reservoir; no condensation will then occur.

The amount of ammonia must be proportioned to the volume of the steel tube or other container used for pressure nitriding. Assume, for example, that a 1½-in. inside diameter pump barrel 20 ft. long is to be nitrided. Its internal volume is 425 cu.in. or 0.25 cu.ft. Nitriding is to be done at 600 psi. From Fig. 7 the density of ammonia vapor at 1000° F. and 600 psi. is 0.66 lb. per cu.ft. The amount of ammonia required in the capsule is therefore 0.66 × 0.25 or 0.165 lb. Liquid ammonia at −50° F. (the temperature of the dispenser in Fig. 2) weighs 0.0252 lb. per cu.in.* The capsule should contain, therefore, 0.165 ÷ 0.0252 or 6.6 cu.in. of liquid ammonia, which is conveniently measured by a capsule base made of ¾-in. schedule 80 pipe (extra strong pipe, 0.742 in. inside diameter) 15¼ in. long. In practice, capsules can be of standard lengths because the ammonia requirement is not exacting – the only precaution really necessary is to avoid over-pressure.

The solid line of Fig. 7 was obtained by extrapolating published data on the thermodynamic properties of ammonia, which are limited to a temperature of approximately 400° F. The actual pressures existing in a nitriding vessel will be somewhat higher than this because of increasing dissociation of ammonia at higher temperatures.

The pressures shown in Fig. 7 could be doubled if the ammonia were to dissociate completely into N_2 and H_2, inasmuch as there would then be twice as many gas molecules. However, even then the pressure could double only if no nitrogen combined with the steel, and there were no loss of hydrogen by diffusion. In our experiments and practice we have observed no pressures more than 11% above the values shown in Fig. 7. In a typical run an initial pressure of 700 psi. would increase to 775 psi. in about 6 hr., thereafter decreasing gradually with time, reaching 700 psi. again 27 hr. after start of the run, and 660 psi. at 29 hr., when the run was completed.

*Variations in the weight of liquid ammonia with temperature are as follows:

Temperature	Weight, Lb. per Cu.In.
−100° F.	0.0263
−75	0.0257
−50	0.0252
−25	0.0246
zero	0.0240
+25	0.0234
+50	0.0226
+75	0.0218

Nitriding Standard Steels

We will now report on experimental and pilot plant nitriding (under pressure) of two commercial types of nitriding steels whose chemical analyses follow:

Element	Type N	Type 135
Carbon	0.24%	0.35%
Manganese	0.56	0.46
Phosphorus	0.013	0.007
Sulphur	0.008	0.013
Silicon	0.29	0.18
Nickel	3.31	None
Chromium	1.23	1.45
Molybdenum	0.26	0.37
Aluminum	1.54	1.26

Pressure – To determine the effect of pressure, a systematic series of tests was made with normalized Type N and normalized Type 135. Referring to Fig. 8 for Type N, it is seen that there is a considerable increase in the rate of nitriding, as well as in maximum hardness obtained, when the ammonia vapor pressure is increased from 100 to 200 psi. Advantages of high pressures are less marked as pressures are further increased from 200 to 2000 psi. (These tests were made in a stainless steel pressure vessel containing a large excess of ammonia vapor, and there was no effect of a diminishing ammonia supply to influence the rate of nitriding toward the end of the run. All hardness tests were made with a Bergsman microhardness tester with a 200-g. load, and all values are in Vickers diamond pyramid numbers.)

Figure 9 shows results of nitriding Type 135 for 15 hr. at 1000° F., with pressures varying from 100 to 2000 psi. These tests show the same trend as obtained with Type N; however, the lowest pressure of 100 psi. gave a maximum hardness almost equal to any of the other runs, and there was not such a pronounced difference in case thickness between low and high pressures. Case depths were around 0.009 to 0.010 in. for pressures of 400 psi. and greater.

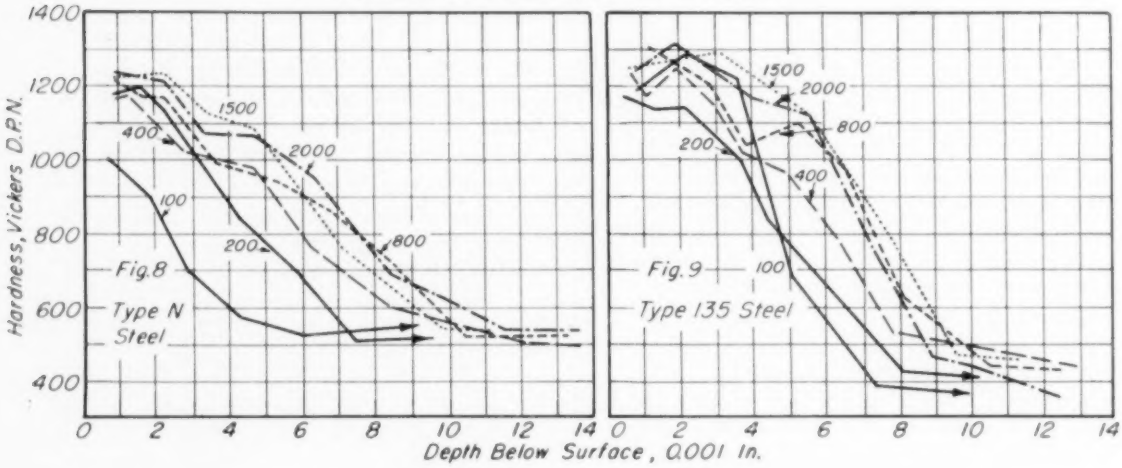
Temperature – Considerable data exist showing the effect of temperature on the characteristics of the case produced in conventional nitriding. To establish comparative values using the pressure method, samples of normalized Type N nitriding steel were nitrided at 800, 900, and 1000° F., for 15 hr., using 10 g. of NH_3 per sq.ft. of surface to be nitrided in a volume giving a pressure of approximately 800 psi. at 1000° F.

Hardness penetration curves for these specimens are shown in Fig. 10, along with those from runs at 1000° F. for 45 hr. (approximately 400 psi. at the nitriding temperature) and 1200° F. for 40 hr. (450 psi.) each having only 5 g. of NH_3 per sq.ft. of surface.

These results seem to parallel those of many investigators who worked with the conventional nitriding process, and show that as the temperature drops much below 1000° F., the rate of penetration becomes too slow for commercial use. While increasing the temperature greatly accelerates the penetration, it is accompanied by a marked falling off in case hardness.

Time as a variable was studied. It should be remembered that, contrary to conventional practice in nitriding with free gas, it is impossible to add to the amount introduced in the capsule and so replace the ammonia consumed in the reaction.

Fig. 8 and 9 – Effect of Variation in Ammonia Pressure When Nitriding 15 Hr. at 1000° F.



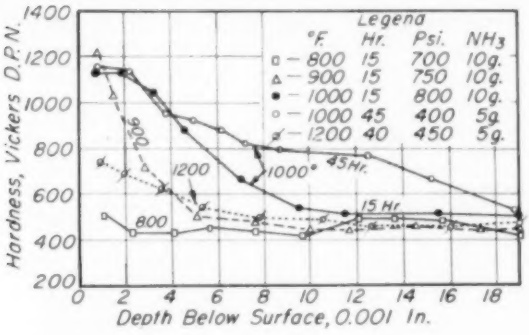


Fig. 10 – Effect of Temperature in Pressure Nitriding

With short pieces of steel tubing of Type N analysis to contain the specimens to be examined and using 10 g. of ammonia per sq.ft. of exposed surface and a space which gave a pressure of approximately 800 psi. when first heated to 1000° F., a series of runs was made at 4, 15, 45, 60 and 90 hr. at temperature. Table I shows the physical properties determined on the resulting case obtained on Type N and Type 135 samples, both in the normalized and quenched-and-tempered conditions.

Compared with data contained in V. O. Homerberg's "Nitralloy and the Nitriding Process", our results indicate a considerably deeper case at the end of 4 hr. over that obtained by conventional nitriding, and a gradual decrease in rate at longer times until at 45 hr. both methods are about equal. After 60 and 90 hr. the rate of increase of case thickness has fallen off considerably but it is interesting to note that the percentage of case which is harder than 700 D.P.N. has increased along with a decrease in the proportionate amount of white layer – whose quantity, in fact, is definitely less than published figures for conventional nitriding. It is questionable whether the surface layer obtained in pressure nitriding is comparable to the white layer of the conventional process. Micro-examinations show definite structure within the apparent white layer, and microhardness traverses do not indicate the characteristic brittleness.

Examination of the table indicates that the thickness of the case harder than Vickers 700 D.P.N. and the total thickness of case (depth at which the core hardness is reached)

Time, Temperature and Case Depth

both increase fairly rapidly to 45 hr. and somewhat less rapidly thereafter. White layer reaches a maximum at 45 hr.; at 60 and 90 hr. its thickness recedes to about what it was at 10 to 15 hr. In all of these tests nitrided Type 135 gave figures slightly higher than Type N. Type 135 reached its maximum hardness after 15 hr., and thereafter softened slightly; Type N gave high hardnesses for all nitriding times between 15 and 60 hr.

Composition of Residue Gas – While the process of pressure nitriding may be explained by the theory of cyclic reactions of dissociation and fixation, there has been no opportunity to trace this reaction while at the nitriding temperature. However, by recording pressures and by analyzing the residue gas after cooling to room temperature, it is possible to get some idea as to the extent of this reaction with respect to time. The table on the following page gives the results of such determinations after nitriding for the indicated times and then cooling to room temperature.

The rise in pressure at the end of the 4-hr. run is undoubtedly the result of dissociation occurring at a greater rate than the nitrogen could unite with the steel surface and before the hydrogen had diffused through the con-

Table I – Variation of Nitrided Case With Time*

(Figures for quenched and tempered samples in italic)

Dimension	Hours at Temperature				
	4	15	45	60	90
			Type 135		
Total case	0.0085	0.0095	0.0190	0.0180	0.0212
	0.0070	*0.0120*	*0.0200*	*0.0190*	*0.0240*
Maximum hardness	1180	1225	1195	1225	1185
	1225	*1250*	*1215*	*1195*	*1160*
Depth over 700 V.P.N.	0.0032	0.0062	0.0150	0.0163	0.0197
	0.0033	*0.0067*	*0.0148*	*0.0161*	*0.0195*
White layer	0.0003	0.0005	0.0011	0.0004	0.0007
	0.0003	*0.0007*	–	*0.0005*	*0.0005*
			Type N		
Total case	0.0090	0.0105	0.0185	0.0190	0.0235
	0.0055	*0.0095*	*0.0190*	*0.0160*	*0.0240*
Maximum hardness	1035	1130	1150	1150	1100
	1065	*1130*	*1010*	*1125*	*1100*
Depth over 700 V.P.N.	0.0034	0.0064	0.0144	0.0162	0.0196
	0.0028	*0.0069*	*0.0128*	*0.0128*	*0.0146*
White layer	0.0002	0.0004	0.0010	0.0003	0.0008
	0.0002	*0.0006*	–	*0.0004*	*0.0005*

*Temperature, 1000° F.; pressure 800 psi.; 10 g. ammonia initially per sq.ft. exposed area.

tainer to any extent. As time goes on, the hydrogen seems to maintain a balance around 30%, with a gradual increase in nitrogen beginning at the time when the rate of case formation is materially slowed down.

Nitriding Time	Pressure	Analysis of Residue Gas NH_3	N_2	H_2
Start	120 psi.	100%	–	–
4 hr.	195	76	16%	8%
15	115	48	29	23
45	95	39	28	33
60	60	26	38	36
90	30	7	67	26

Contamination With Water and With Air – In the conventional nitriding processes it appears to be important to use drying agents to remove all traces of water from the ammonia vapor. When nitriding by the method illustrated in Fig. 1, it is inconvenient to exclude air (and water vapor contained in the air) while welding on the end plugs.

In order to determine whether it was necessary or desirable to exclude air, tests were made with dry air, air with approximately 50% humidity, with the nitriding container free of air after purging with nitrogen, and with various quantities of water deliberately added to the nitriding container – which, in this test, consisted of a 1½-in. i.d. by 6-in. tube charged with liquid ammonia to give a pressure of about 800 psi. at the nitriding temperature of 1000° F. All samples were nitrided for 15 hr.

Results on Type N steel, normalized at 1650° F. before nitriding, are as follows:

Original Atmosphere	Total Case	Case >700 D.P.N.
Dry air	0.0100 in.	0.0076 in.
Dry nitrogen	0.0095	0.0071
50% humidity at 75° F.*	0.0110*	0.0085*
Air plus 0.05 g. H_2O	0.0114	0.0086
Air plus 0.10 g. H_2O	0.0120	0.0098
Air plus 0.15 g. H_2O	0.0110	0.0088

It appears that precautions to eliminate air and water vapor are not necessary, inasmuch as any noticeable effect was a slight improvement on the rate of nitriding, as water vapor increased. The only detrimental effect noticed was a surface stain which could be easily polished off to give a bright finish.

*Corresponding figures for Type 135 steel previously quenched from 1650° F. and tempered at 1100° F. are 0.0110 and 0.0076 in. respectively.

Ammonia Consumption – It was stated previously that ammonia consumption could be reduced as much as 95% by using the high-pressure process. Typical published requirements for the conventional technique are 20 to 30 cu.ft. of ammonia vapor per hr. per 100 sq.ft. of surface nitrided. Comparing these figures with the four values shown in Table I for Type N and Type 135 at a nitriding time of 45 hr., when a case depth of 0.019 in. is obtained by both processes, the conventional process requires 40.5 to 60.8 lb. of ammonia per 100 sq.ft. of surface nitrided for 45 hr., while the high-pressure process required only 2.2 lb. This represents a reduction of 94.5% to 96.3%. We believe these figures are conservative, having obtained equal results with only 1.1 lb. of ammonia per 100 sq.ft. Ammonia savings will vary with conditions, but for most practical applications the pressure method should save at least 90%.

While there is considerable latitude for varying both pressure and volume and still obtaining an adequate charge of ammonia for most nitriding requirements, optimum conditions have not yet been determined and this question justifies further investigation.

An example of the possibilities is the nitriding of the inner surface of a circular cylinder or tube. The area to be nitrided varies as the first power of the diameter while the volume varies as the square of the diameter – that is to say, if the diameter is doubled for a given length, the surface area is doubled but the volume is increased four-fold. Therefore, the pressure can be reduced 50% and still retain an equal ammonia charge per unit of surface area. Figures 8 and 9 indicate that pressures can vary between 400 and 2000 psi. without greatly altering the characteristics of the case.

Quality Control – During about two years of nitriding on a commercial basis by this method (case hardening the inner surface of pump barrel tubes) we have made a practice of inserting a small test specimen, generally a ¼-in. rod about 1 in. long, into the nitriding container. These test specimens ordinarily are fractured to obtain a rough indication of case depth; if a more thorough examination is wanted, a photomicrograph of this specimen can be made as well as a microhardness traverse. We have found that a fracture test is not always reliable; hardness traverses of specimens that did not show any indication of a case would indicate a perfectly normal case for the time and temperature utilized. Apparently the cooling rate influences the appear-

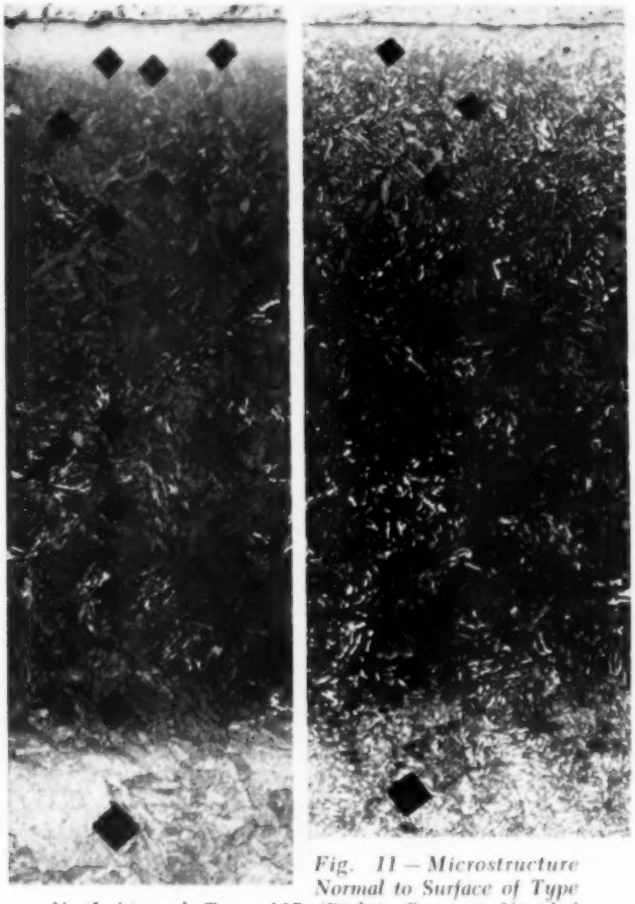


Fig. 11 – Microstructure Normal to Surface of Type N (Left) and Type 135 (Right), Pressure Nitrided 45 Hr. at 1000° F. and 800 Psi. × 250, 5% nital etch

ance of the case when fractured; this point deserves further investigation.

When nitriding at 1000° F., we have found that – if the pressure is maintained at the proper value throughout – a satisfactory case will result on properly prepared material. When nitriding the inner surface of seamless tubes by the capsule method, we have devised a method for measuring pressure after nitriding is completed and the tube is cooled to room temperature. This is done as the end plug of the tube is drilled to vent the remaining gas. (See Fig. 5.)

Practically the only source of trouble is an occasional small leak in the weld at one of the ends; gradual leakage during nitriding will result in a case thinner than expected. When nitriding at a pressure of 600 to 700 psi., and a pressure of 100 psi. or more exists at room temperature after nitriding, the process is almost certain to be successful. We have found very little difficulty with leakage at the plug, and when a tube is found that has a low pressure, it is not lost but the plug may be machined off, a new charge of liquid ammonia inserted, new end plug welded on, and the tube re-nitrided.

Containers – It has been pointed out rather frequently in the literature that common carbon steel or low-alloy steel containers are unsatisfactory for nitriding by the conventional atmospheric pressure process. This is stated to be the result of a catalytic action after the steel absorbs some nitrogen from the ammonia; it is then difficult to control the percentage decomposition necessary for satisfactory nitriding. Apparently the ammonia breaks down too rapidly; presumably it is also detrimental to have the ammonia break down in contact with the container's surface, inasmuch as the nitrogen atoms may then regroup as molecules and become inactive before they reach the surface to be nitrided.

This has not proved to be a difficulty when nitriding under pressure inasmuch as we have utilized S.A.E. 1020 steel tubing for containers for nitriding other parts, including rods and tubes which were to be nitrided on the outer surface.

Since the reaction is reversible under high-pressure nitriding conditions, any influence that common steels may have on the rate of ammonia dissociation does not appear to be significant to the final result.

Microstructure and Hardness – To obtain a flat specimen without rounding off the edges, samples of machined rods, $\frac{5}{16}$ in. diameter, have a $\frac{3}{16}$-in. wide flat ground along one element before nitriding. After nitriding, pieces are cut off and mounted in pairs, flat against flat with copper foil between, and forced together as tightly as possible with an Allen set screw through the side of the mount or holder. The assembly is then placed in the mounting press and embedded in lucite, thus making a convenient specimen for the microscope as well as for the Bergsman hardness test. The micrographs of Fig. 11 show the copper foil at the top as well as the hardness impressions.

Phosphate Coatings Benefit Metal Finishing and Working

By ALLEN G. GRAY

BY PROPER CHOICE of solution and conditions, it is possible to produce phosphate coatings especially suited for a variety of uses, such as paint bonding, corrosion protection, lubrication and wear resistance. These so-called conversion coatings consist of insoluble metallic phosphates formed by chemical modification of the metal surface. Experience gained during and since World War II has emphasized the importance of phosphate coatings in defense production.

As a part of a discussion on substitute finishes for electroplating featured at the 38th Annual Convention of the American Electroplaters' Society, Alfred Douty, chief chemist, American Chemical Paint Co., cited a number of reasons (summarized in Table I) for applying phosphate coatings. The type of phosphate coating applied to a component may vary with the intended use of a part, that is, whether structural or mechanical. Structural parts, such as exterior surfaces of vehicles, artillery mounts, and field carriages are almost always phosphated as a part of the finishing schedule. Another type of phosphate coating with a supplemental oil dip is used on such items as gear trains and mechanical frictional components.

Paint Base – Phosphate coatings for use as a paint base are usually applied (either by immersion or by spraying) after fabrication of articles and immediately before painting. Small parts which can be more conveniently handled as a unit load are treated by immersion, while the spray method is used with larger parts, as for the automobile bodies in Fig. 1.

Phosphating materials are also available for use in both a cleaning and phosphating function. According to E. F. Houghton & Co., an acid phosphate cleaner which incorporates excellent wetting ability and detergency removes the soil from metal and supplies a light phosphate coating to provide increased adhesion for painting, japanning or lacquering. Ferrous metals soiled with oils, rust preventives or dirt are easily cleaned in this type of bath; the impervious film it forms also protects against corrosion. The Diversey Corp. also makes a compound of this kind. Figure 2 shows a conveyerized installation for cleaning, phosphating, and drying parts.

The corrodibility of a metal in the environment in which it is used is known to affect the protective life of paint coatings. Surface treatment is an important factor in preparing

Table I – Reasons for Applying Various Types of Phosphate Coatings

REASON FOR USE	TYPE OF COATING
Corrosion retardation under paint.	Zinc-iron phosphate (150 to 450*) Iron phosphate (30 to 60*)
Corrosion retardation of plated coatings (such as zinc and cadmium) under paint.	Zinc phosphate
Corrosion retardation with the aid of oily or waxy after-coatings.	Zinc-iron phosphate Manganese phosphate (3000*)
Improved wear resistance, as on camshafts, piston rings, valve tappets and gears.	Manganese-iron phosphate
Aid to drawing, forming, polishing, as on wire, tubing and flat polished steel.	Zinc-iron phosphate (700 to 2000*)
As a dry coating without after-treatment to retard corrosion.	Zinc-iron phosphate Manganese-iron phosphate (3000* or more)
Electrical insulation, as on transformer laminations and iron powder for magnetic cores.	Zinc-iron phosphate (3000* or more)

*Mg. per sq.ft.

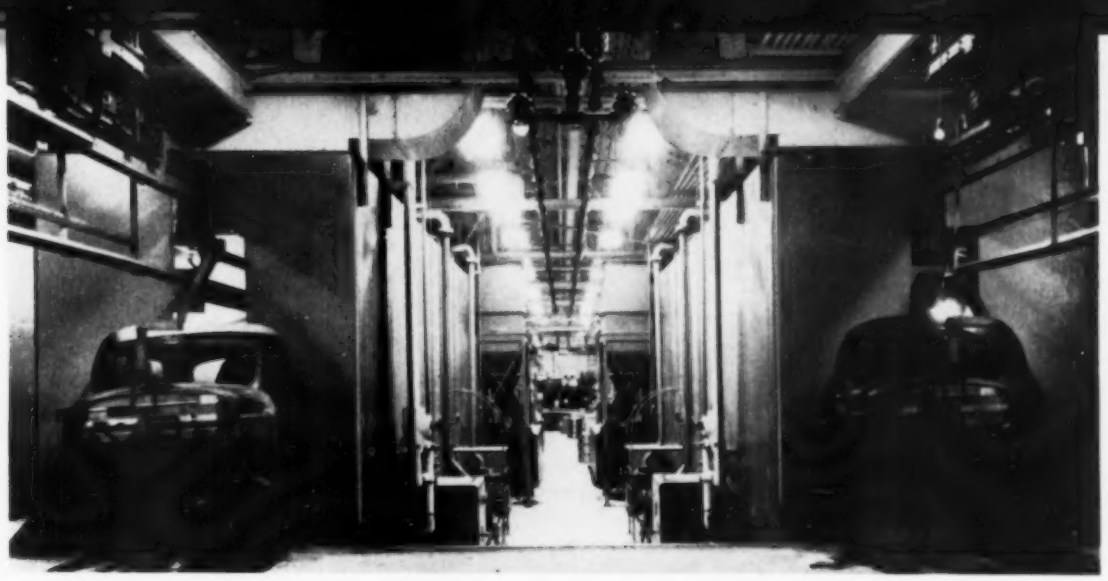


Fig. 1 – Cleaning and Rustproofing Machines in Two Production Lines at DeSoto Plant of Chrysler Corp., Detroit. (Courtesy R. C. Mahon Co.)

metals for painting. Without exception, treatments recommended by investigators in this field have as their main objective the formation of a stable and nonreactive coating which combines chemically with the base metal and thereby retards corrosion and improves adhesion of organic finishes. Phosphate coatings reduce the activity of the metal surface; this retards the spread of corrosion from scratched or abraded areas in the paint film. Figure 3 shows results of 6 years of outdoor exposure tests on bare steel, sand-blasted steel, and phosphate-coated steel, all of which were finished with two coats of enamel.

The phosphates of iron, manganese and zinc in dilute phosphoric acid solutions are most commonly used. The most adherent of these coatings are thought to be those containing a portion of iron phosphate in combination with the metal phosphate employed in the phosphating baths. Thus, for the widely used zinc phosphate type of solution, the coating composition would be zinc phosphate plus iron phosphate. Table II on the next page gives data on corrosion resistance of untreated and phosphate-coated steel.

Conversion of zinc surfaces to a phosphate coating is effectively used to inhibit corrosion and to prevent reaction of the paint vehicle with the metal. Zinc and cadmium-plated steel, galvanized iron and zinc-base die castings may be phosphated to improve paint performance. Phosphating of aluminum improves paint performance and permits the use of a wide variety of paint compositions which cannot be used effectively over untreated aluminum surfaces. Zinc and steel parts can be processed in the same solution as used for aluminum, which is an advantage for plants where mixed production of these metals is involved.

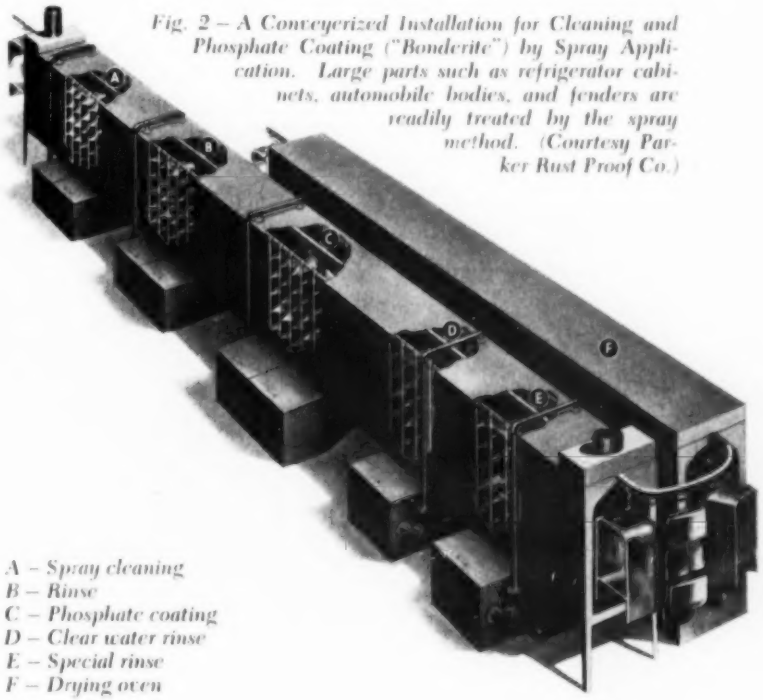


Fig. 2 – A Conveyerized Installation for Cleaning and Phosphate Coating ("Bonderite") by Spray Application. Large parts such as refrigerator cabinets, automobile bodies, and fenders are readily treated by the spray method. (Courtesy Parker Rust Proof Co.)

A – Spray cleaning
B – Rinse
C – Phosphate coating
D – Clear water rinse
E – Special rinse
F – Drying oven

Fig. 3 – Results of 6-Year Outdoor Exposure Test on Bare Steel, Sand-Blasted Steel, and Phosphate-Coated ("Bonderite") Steel Finished With Two Coats of Baked Synthetic Enamel. (Courtesy Parker Rust Proof Co.)

Corrosion-Preventive Uses – The affinity of heavy phosphate coatings for oil and wax is one of their most valuable characteristics and is used to enhance their corrosion resistance. Frequently, coated parts are finished by dipping in nondrying-type oils containing corrosion inhibitors, followed by centrifuging to remove the excess. Protection is improved if the phosphate coating is given a final rinse in a weak chromic acid solution and then sealed with a rust preventive oil, compound, or wax. During World War II many small arms were rustproofed by phosphate coating, followed by a chromic acid rinse, and a rust preventive oil or cutback petroleum.

Table II – Corrosion of Untreated and Phosphate-Coated Steel*

Conditions	Weight Loss, Mg. per Sq.Cm.	
	Untreated	Phosphated
744-Hr. salt fog test	34.08	3.32
1 Year rural exposure	20.39	1.60

*Based on tests by Parker Rust Proof Co.

The nature of phosphate coatings produced for this purpose is such that they absorb and hold relatively large quantities of the sealer, yet present a surface "dry" to the touch. Typical application of zinc-iron phosphate coatings for corrosion is immersion of parts in the solution for 30 to 60 min. at 190 to 200° F.; the resulting coating would be in excess of 3000 mg. per sq.ft. Figure 4 shows ferrous parts that have been coated with zinc-iron and manganese phosphates (in this instance "Permadized" and "Thermoil-Granodized" with American Chemical Paint Co.'s rustproofing processes). Rustproof finishes of this chemical type are used on

Fig. 4 – Ferrous Parts Phosphate Treated and Then Sealed With a Rust-Preventive Oil for Effective Protection. (Courtesy American Chemical Paint Co.)

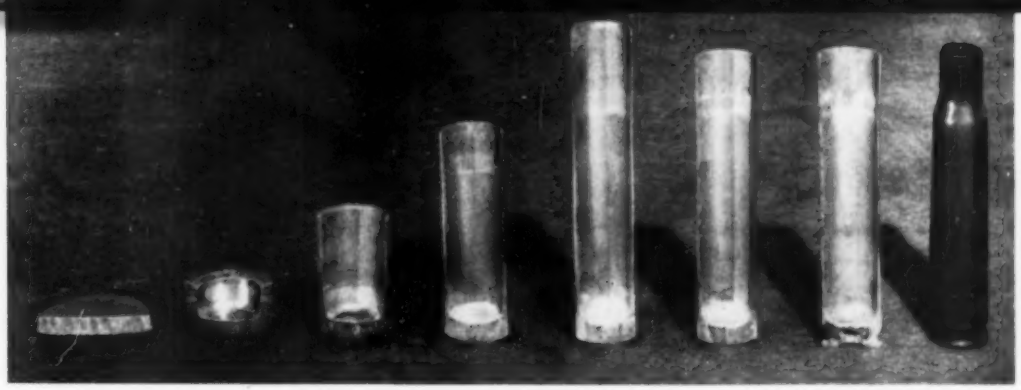


Fig. 5 – Progressive Stages in Cold Drawing of 50-Caliber Steel Cartridge Cases. A phosphate coating makes the operations smoother, reductions greater, and production levels higher. (Courtesy Parker Rust Proof Co.)

hardware, ordnance items, forgings and castings, tools, and machine parts. In addition to improved corrosion resistance such treatments also give a dull black, nonreflecting surface.

Metalworking Aid – Phosphate coatings have improved the efficiency of cold-forming operations on steel. Reduced friction, faster drawing, reduced power consumption, and improved tool and die life are advantages based on plant experience (see "Surface Treatment for Cold Extrusion", *Metal Progress* for December 1951, p. 76). The combination of adherent phosphate coating and adsorbed lubricating film has a low coefficient of friction while maintaining its integrity under extremely high deforming pressures. Figure 5 shows progressive stages in cold drawing of 50-caliber steel cartridge cases using the "Bonderite" (zinc-iron phosphate) type of coating. Other phosphate coatings for this purpose are "Extrudicoate" (Detrex Corp.), "Foscoat" (Pennsylvania Salt Mfg. Co.), and "Granodraw" (American Chemical Paint Co.).

According to Parker Rust Proof Co. there are three main reasons why "Bonderite" coating facilitates the drawing operation to such a great extent. The first is its singular action when combined with the lubricating agent. The phosphate coating, integral with the metal surface, reacts with the lubricating solution to form a water-insoluble soap which in itself becomes an integral part of the phosphate coating. Second, the coating takes part in the drawing operation. It undergoes ironing in the die, but being in effect a part of the metal surface, it becomes thinner, yet remains a uniform, tightly adherent layer. Third, since the phosphate is a nonmetallic separating layer, it acts as an antiflux and aids materially in preventing welding and galling. Phosphate coatings are used also in cold working of zinc-coated steel, stainless steel and aluminum.

Phosphating is used on flat-polished steel to prevent scratches and die marks in the forming operation. The type of treatment used for this is basically the same as for paint bonding, as distinguished from the type used for deep drawing. Phosphating effectively reduces wear on bearing surfaces. With cast iron or steel, the manganese-iron phosphate type of coating provides an effective wear resistant layer.

Fig. 6 – Production of Tubs for Washing Machines Increased 140% With Aid of Phosphate Coating at Heintz Mfg. Co. (Courtesy Pennsylvania Salt Mfg. Co.)

Light Metallurgy

Sonnets for the Metallurgist

IN THESE PROSAIC and decadent days no one thinks of writing sonnets to metallurgists. It was different in Florence, in the high old days of metallurgy, under the Medicis. Any small jobbing foundryman turning out stock Apollos and Cupids expected to have his works flowerily praised in verse; and the greatest bronze founder of them all, Benvenuto Cellini, reckoned up his sonnets as eagerly as a film star weighing his fan-mail, and for much the same reason – the number of ducats the Duke paid him depended on a measurable amount of public acclaim.

He left behind a detailed account of his greatest metallurgical feat, the casting of his Perseus. The operation is distinguished by many remarkable and unusual features; for one thing, the foundry was on fire during the whole of the casting process, an interesting circumstance rarely if ever experienced today.

Grave difficulties attended the manufacture of the statue from the very beginning. In the first place, Benvenuto was really a goldsmith; he only took to foundry practice in late middle age because the Duke took it into his head that he would like a great statue of Perseus for his fine piazza. Benvenuto had many faults, including a phenomenally ebullient and cantankerous disposition, but he was certainly not lacking in self-confidence, and as soon as he received the Duke's command he set to work to plan and build a foundry and to obtain a little preliminary experience in the art.

He had only recently returned from a long sojourn abroad, but he had had ample time to quarrel with nearly everybody in Florence, including the Duke's major-domo. His early operations were seriously hampered by these personal disputes. He found a convenient house, and had marked out the plan of his foundry in the garden and chopped down half the trees and vines to make room for it, when the major-domo suddenly popped up and asked whether he had any right to occupy that particular house at all. This matter was settled, but the major-domo kept him perpetually short of lime, sand, building stone and money, with the result that Benvenuto's foundry was never quite the dream-edifice he had planned.

The law in Florence at that time consisted very simply of what the Duke happened to say at any given moment. Every time Benvenuto detected a cold look in his eye, which naturally happened from time to time, he had to decamp hurriedly to Rome or Venice and stay there until word reached him that the Duke was in a happier mood. He also had to keep on the right side of the Duke's consort; this entailed long spells of complete neglect of his Perseus while he made rings, vases and golden belts for the Duchess.

Nevertheless, he plodded on. He laid in stocks of clay, bronze and pine logs from Monte Lupo; he did the preliminary bashing and bending of the iron bars (which were to form the framework of his statue) in the cellar of his house, while the foundry in the garden slowly arose; and he obtained what little practical experience he felt he needed by casting a bust of the Duke in the workshop of one Poggini, a bell-founder with whom he had unaccountably refrained from quarreling. At length the foundry was completed, and, with a fluctuating staff of about ten men, master-founders, laborers, peasants and apprentices, he launched himself on the final phase of his operations.

He naturally employed the conventional lost-wax process. The basis of his Perseus was (and, no doubt, still is, under the bronze) a great skeleton of iron bars. This he covered with clay, roughly in the form of the finished statue but half an inch within the surface of the eventual statue. After baking the clay well, he spread wax thickly over its surface and modeled it till he had the finished statue, in wax, to his liking. It showed Perseus in the act of slaying Medusa. Her body lies at Perseus' feet, and he is holding aloft her serpent-wreathed head.

Benvenuto had a final, but fortunately a minor, quarrel with the Duke about the Medusa's head. The Duke, who had been chatting to some of his rivals, held that the bronze would never rise up Perseus's arm and fill it. Benvenuto, with small delay and ineffable complacency, put him right on this point. "It is in the nature of fire to ascend," he said, "and therefore the bronze will rise and fill the head perfectly." What really bothered him was on the other end, the right foot of Perseus, but he could always add it if it turned up missing.

Having dismissed the Duke in a pardonably irritated condition, he set to work to cover the

wax with further layers of clay, leaving numerous vent-holes for the wax to run off. This outer mold he strapped around and supported with more iron bars, and then, having his clay-covered and iron-bound wax Perseus standing upright in the middle of the foundry, he built up around it a brick furnace. With a slow fire of pine logs he drew off the wax, and, when the wax had all run out, threw on more pine logs to bake the clay mold. This fire they kept up for two days and two nights on end, till the clay was thoroughly hard.

The problem now was to get the Perseus low enough so the molten bronze would run from the furnace into the mold, and they solved it by digging an enormous hole in the floor by the side of the same funnel-shaped brick furnace, which, having baked the mold, was now destined to melt the bronze. Then, by means of windlasses and strong ropes, they hauled the mold out of the furnace till it was dangling from the roof, two feet clear; then they swung it over and let it down to the bottom of the pit. When it was settled securely in the pit they shoveled the earth back, keeping the vent-holes open by running little trains of terra-cotta pipes up to the surface.

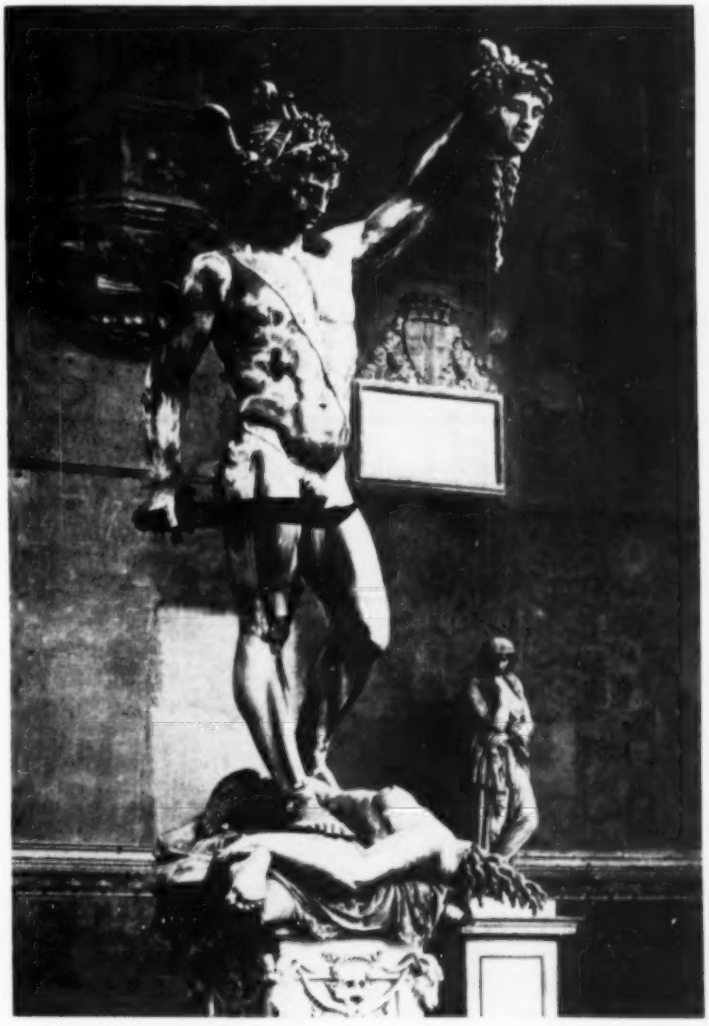
Now they filled up the furnace with pigs of copper and pieces of bronze, laid across each other so that the flames could swirl freely around them. "In great excitement," says Benvenuto, "I ordered them to light the furnace . . . what with the unctuous pine resin and the well-contrived draft, the fire burned splendidly. . ."

It burned so splendidly, in fact, that almost at once the foundry roof caught fire! Fire-fighting operations were hampered by a great storm which sprang up at the same time. It may have dampened down the fire, but it also blew great gusts of wind and rain in through the side of the shop, which appears to have partially collapsed into the garden, so they had great difficulty in keeping the furnace hot. On the top of these disasters, Benvenuto suddenly felt a fever of indescribable severity, and he collapsed on his bed, imploring his men to continue the struggle in his absence. After incoherently instructing his chief apprentice, Bernardino, how to draw out the plugs of the furnace when the metal was melted, he sank into a stupor, murmuring, "By tomorrow morning I shall be dead."

His fever mounted steadily for some hours, till he had a terrible nightmare which awakened him, and he rushed back to the shop where he found his men standing about dazed and at their wits' end. The fresh Florentine air was blowing in in such quantities that the metal had, as he says, coagulated.

It was a crisis, but not one to floor Ben-

Cellini's Perseus, Now at Loggia dei Lanzi, Florence, Italy. (Courtesy Cleveland Museum of Art)



Oak and Pewter for the Foundry

venuto. He was the kind of man who liked to know all the details of what was going on in the town, and he happened to know that Capretta, the butcher opposite, had a load of young oak logs which had been dry for more than a year. He sent two men across to borrow or steal these; and when they came back with them he hurled armful after armful into the pit. Oak, as he explains, makes a fiercer fire than any other sort of wood. The furnace blazed up; likewise the fire on the roof broke out again with unprecedented ferocity. He sent two men up there to keep it under control, and another detachment to pile up planks, rugs and hangings at the side of the shop where the weather was pouring in.

Gradually the metal began to melt, but it was still sluggish, so they flung in a pig of pewter weighing about 60 lb. What with the depression of the liquidus, the oak logs, and a certain amount of prodding and stirring, the mass was looking more promising, when all at once the top of the furnace blew off.

Benvenuto's fever by now had completely gone. He saw liquid bronze running out the furnace, and immediately ordered his men, who were still dazed by the explosion, to draw out the plugs. The metal ran down the channels toward the mold, but it was still sluggish. Without hesitation he sent his men to scour the house for every pewter dish, porringer and plate. They found nearly 200, and Benvenuto used them all. Some he laid in the channels, and the rest he flung into the furnace. At last the metal ran merrily. "In an instant my mold filled up," he says. "I knelt down and thanked God with all my heart; then turned to a plate of salad lying on a bench there, and with splendid appetite ate and drank."

It was two hours before dawn, and he went and slept till dinnertime. But before anybody could have dinner, as he records, his family had to go off and buy pots and pans of earthenware to take the place of the pewter vessels.

The Perseus was soon out on the piazza. The Duke persuaded him to unveil it for an hour or two, before it was really finished. (The right foot, as he prophesied, was partly missing.) As soon as the people caught sight of it there arose a great shout of applause; and from then on they began to pin sonnets in its praise on the doorpost.

Unfortunately Benvenuto could not live on sonnets alone, even in 16th-century Florence. Getting ducats out of the Duke proved to be more difficult than getting sonnets out of the Florentine public. The modern foundryman may congratulate himself on escaping many of the hazards, such as temperamental Dukes and infinitely combustible foundries, that beset Benvenuto. On the other hand, the modern is usually inhibited by restrictive specifications from a proper use of pewter household vessels; he can rarely turn for relief to dry oak logs; and nobody has ever dreamed of pinning sonnets to his doorpost.

R. P. LISTER

Nominating Committee for ASM National Officers

IN ACCORDANCE with the constitution of the American Society for Metals, President RALPH L. WILSON has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), treasurer (for two years), and two trustees (for two years each). This committee was selected by President WILSON from the list of candidates submitted by the chapters. The personnel is:

W. M. BALDWIN, JR. (Cleveland Chapter), *Chairman;* Case Institute of Technology, Cleveland 6, Ohio.

W. B. BILLINGSLY (Montreal Chapter), Canadian Industries Ltd., Montreal, Canada.

FRANK F. FORD (Georgia Chapter), Room 109, 1145 Peachtree St., N.E., Atlanta, Ga.

J. H. GARRISON (Tulsa Chapter), Oklahoma Steel Casting Co., Tulsa, Okla.

GILBERT L. COX (Rochester Chapter), International Nickel Co., Inc., Rochester 4, N. Y.

EARL T. HAYES (Oregon Chapter), U. S. Bureau of Mines, Albany, Ore.

HENRY L. BURGHOFF (New Haven Chapter), Chase Brass & Copper Co., Waterbury, Conn.

JOHN A. GRODRIAN (Notre Dame Chapter), Bendix Products Division, South Bend 20, Ind.

E. H. STILWILL (Detroit Chapter), Chrysler Corp., Detroit 3, Mich.

THIS committee will meet during the third full week in the month of May. It will welcome suggestions for candidates in accordance with the ASM Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but any individual member of a chapter may suggest to the nominating committee any candidates he would like to have in office. Endorsements may be sent in writing to either the chairman or any member of the committee.

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Open-Hearth Grade	50 to 55%	8%	3%
Foundry Grade	50 to 55%	approx. 10%	3%

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	Vanadium Oxide (V_2O_5)	Sodium Oxide (Na_2O)	Calcium Oxide (CaO)
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Photographing Luders' Lines

SPOKANE, WASH.

In an investigation of the formation of Lüders' lines in an aluminum alloy, photographs were required to show the frequency and mode of occurrence of the lines. The method developed for obtaining these might be of interest to others faced with the same problem.

Faint Lüders' lines could be seen only if the sheet had been highly polished before the deformation, but such a highly reflective surface was difficult to photograph because of the glare. With the method used, shown in Fig. 1, light striking the polished aluminum surface was reflected to a photographic emulsion. Development and printing of the film produced the clear photographs of Lüders' lines shown in Fig. 2.

F. M. KRILL
Head
Metallographic Dept.
Kaiser Aluminum & Chemical Corp.

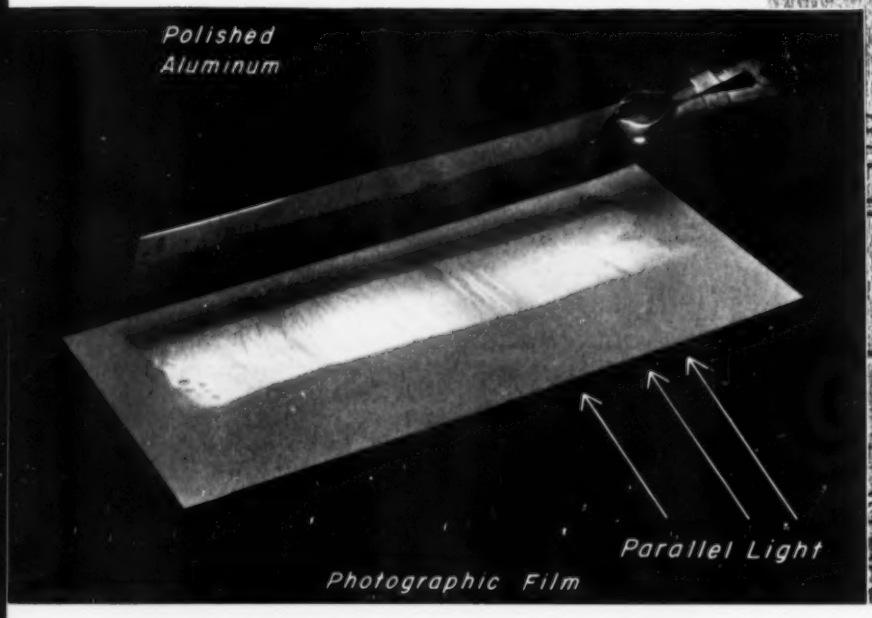

Fig. 1 – Setup Used to Obtain Image of Lüders' Lines

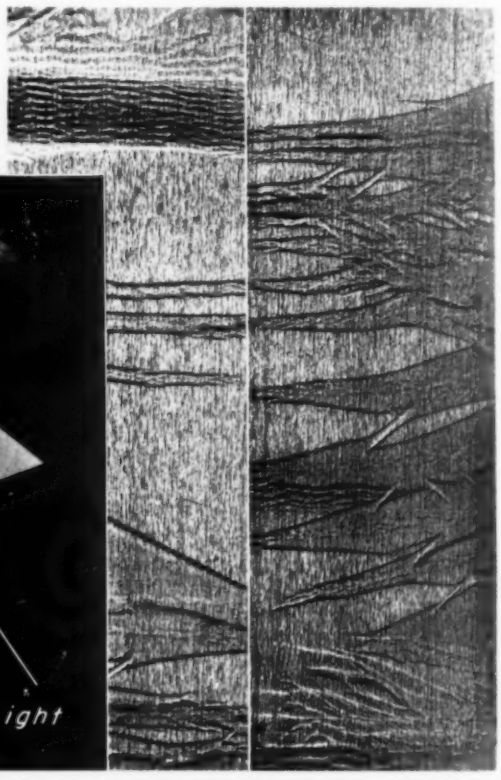

Fig. 2 – Resulting Prints From Developed Negative

Results of Studies on Martensite Formation Not Contradictory

CAMBRIDGE, MASS.

The paper by Kurdyumov, Maksimova and Tagunova which was abstracted by Dr. A. G. Guy in the September 1952 issue of *Metal Progress*, p. 146 ("Effect of Deformation on Transformation of Austenite to Martensite"), appears to have an important bearing on the theory of martensite formation, and is worthy of some comment inasmuch as the findings seem to be at variance with recent work in this country. The Russian investigators report that plastic deformation of austenite above M_s lowers the onset of the martensitic transformation during subsequent cooling. On the other hand, in accord with the strain embryo theory of martensite nucleation, it has been shown ("Burst Phenomenon in the Martensitic Transformation", by E. S. Machlin and Morris Cohen, *Transactions* of the American Institute of Mining and Metallurgical Engineers, Vol. 191, 1951, p. 746) that plastic deformation raises M_s, and

(Continued on p. 116)

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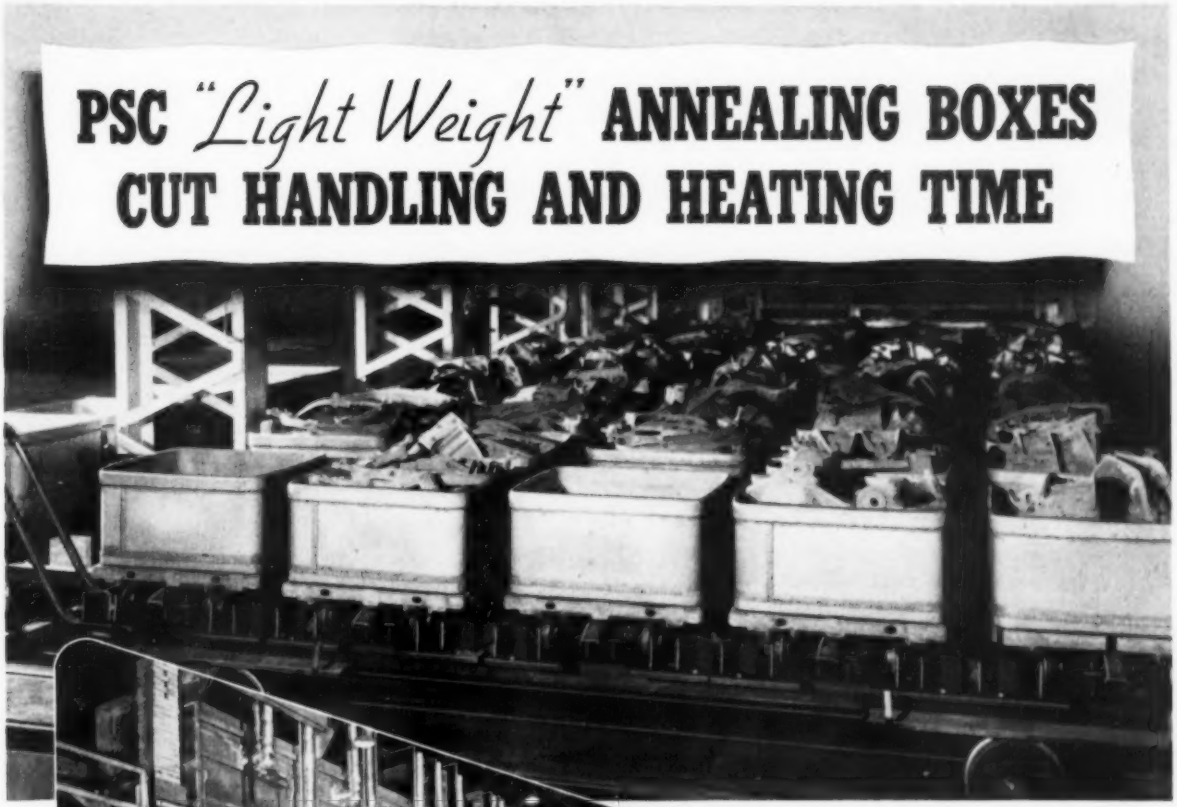

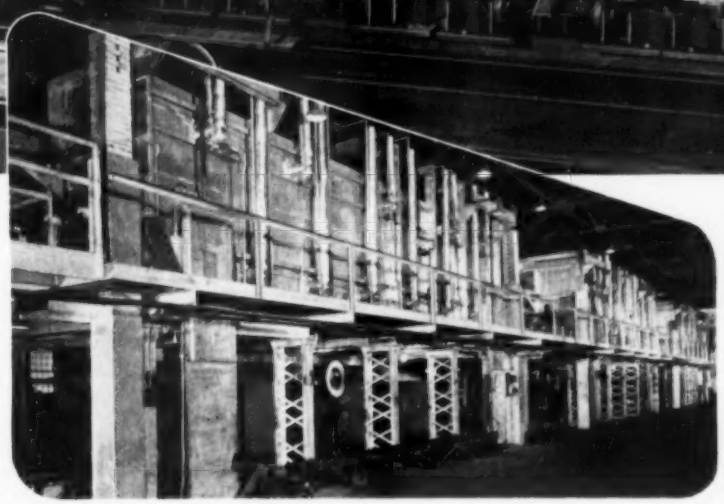

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Results of Studies on Martensite Formation

(Continued from p. 114)

that even elastic stress may raise M_s ("Effect of Applied Stress on the Martensitic Transformation", by S. A. Kulin, Morris Cohen and B. L. Averbach, *Journal of Metals*, Vol. 4, June 1952, p. 661). Thus it becomes necessary to reconcile the apparently contradictory results.

The influence of plastic deformation on the martensitic transformation is rather complex because of the interplay of conflicting factors. Plastic deformation favors the transformation by introducing new embryos and by raising the energy level of existing embryos via the concomitant elastic stresses. Both of these phenomena operate to stimulate the transformation either during the deformation or during the subsequent cooling. However, the partitioning of the austenite tends to oppose the transformation in two ways: *(a)* The size of the martensitic plates is reduced, thereby yielding less martensite per activated embryo and offering less chance for cooperative aid among the individual martensitic units; and *(b)* the effective grain size after complex deformation may be sufficiently small so that it will inhibit the transformation displacements and hence inhibit the transformation itself.

When the above variables are recognized, it is easy to understand that M_s may be raised or lowered by plastic deformation, depending upon which factors happen to predominate. The net effect will vary with the alloy system as well as with the nature and degree of the plastic deformation. For example, one might expect to find systems in which M_s would be first raised by small amounts of deformation and then lowered by further deformation. In the same sense, there may be instances in which the reversal occurs at such a low degree of deformation that the initial increase is negligible. It may also happen that the opposing factors completely overlap, and only the over-riding effect is observed.

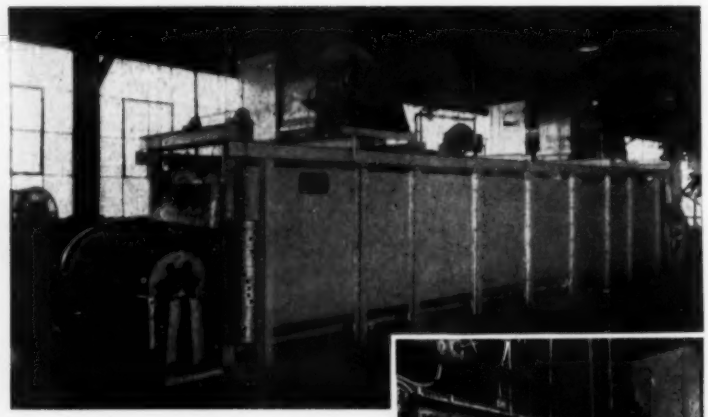
It is worth noting that the detection of the initial raising of M_s due to deformation may depend on the sensitivity of the measurements. In austenitic iron-nickel alloys, plastic deformation raises the M_s but decreases the initial amounts of martensite formed per degree of dropping temperature. The latter effect may be so pronounced that if the method of observation is not capable of ascertaining minute quantities of transformation, the raising of M_s may be overlooked and a cruder determination will indicate an apparent lowering of M_s.

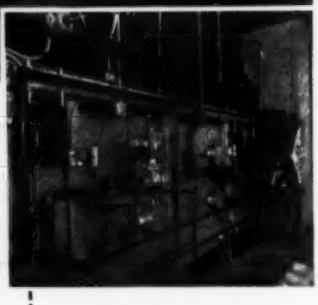
In the light of the several tendencies at play, we may conclude that the results of Kurdyumov and his associates are not contrary to the work reported in this country. Rather, they should be regarded primarily as one aspect of the more general effect of plastic deformation on the martensitic transformation.

Morris Cohen
Dept. of Metallurgy
Massachusetts Institute of Technology

Correction to Stabilized Stainless Steel

The reference to "cobalt-stabilized stainless steel" in the letter from G. W. Weeks (*Metal Progress* for February 1953, p. 116) should have read columbium-stabilized.





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Because of its wide experience in the designing of furnaces for ordnance production, Salem-Brosius will be of considerable value to you if you are considering bomb manufacture. We'll build your bomb nosing and tail forming furnaces, your bomb harden, quench and draw lines, your bomb normalizing furnaces, and supply all the auxiliary equipment necessary to those operations. In fact, you'll save money and assure yourself of fast, economical production (as have many others) if you let Salem-Brosius assume the contract for your entire bomb plant and simply hand you the key. If you are currently considering new facilities or the enlargement of old ones, a talk with our engineers can hardly fail to be a good investment. Write, wire or phone.

SALEM-BROSIUS, INC.

Sales and Engineering Offices: 341 Bourse Building, Pittsburgh 22, Pa.

Advocates Reducing Atmospheres for Castings

HINSDALE, ILL.

In his article "Progress in the Bronze Foundry", *Metal Progress* for December 1952, p. 91, Mr. Roast states, "The result of careful work of a number of scientifically minded observers has been to prove that an oxidizing atmosphere is definitely superior to a reducing atmosphere." There is a question in my mind concerning this statement when made without qualification. Two examples with which this writer is familiar may be cited where good castings are made commercially in a reducing atmosphere. A personal opinion is offered that castings are superior when melting and casting is done under reducing conditions.

The problem in the first example was that of casting: *(a)* A series of copper alloys from 0 to 10% tin, 4 to 25% lead, 0 to 4% zinc; *(b)* bonding these alloys to low-carbon steel simultaneously with casting; *(c)* producing castings with uniform parallel dendritic structure, and free of porosity, inclusions and segregation.

Briefly the process consisted of melting the alloy in an oxidizing atmosphere as a precaution against the presence of dissolved hydrogen. The molten metal was then transferred to a closed furnace. Care was taken to skim any slag present, since slag was associated with unsoundness. The closed furnace contained ¼-in. or larger pieces of electrode carbon. The furnace contained a reducing atmosphere consisting largely of carbon monoxide, low in hydrogen and low in other gases. Castings were made by bottom pouring without the metal passing through air.

In the second example the problem was to produce copper shapes free of copper oxide and gases evolved during solidification. Tough pitch copper (copper melted and cast in air) is characterized by a "level set" or absence of apparent shrinkage due to the evolution of dissolved gases during solidification. (This same gassy condition may also be present in some of the common copper alloys, especially where zinc is low or absent.) In this instance sound, gas-free, oxide-free metal was cast when cathode copper was melted in a furnace containing large

(Continued on p. 120)

Have you investigated

"BORON STEELS"

as a ready means to increased hardenability?

Farm equipment and earth-moving machinery manufacturers are using boron steels for axles, spindles, drive gears and many other heavy section parts.

Boron steels—used for pinions, shafts and heavy-duty gears for air-cooled engines—are helping to meet new requirements in the aircraft industry.

In gears, pinions, axles, springs and many other automotive parts, older grades of alloy steels are now being replaced by boron steels.

Boron steels are enabling manufacturers of hand tools and shop equipment to make significant cuts in their annealing costs.

Millions of tons of boron steels made with Vancoram GRAINAL Alloys are now in service.

These steels are doing many of the jobs formerly done only by the older grades of higher alloy steels. They contain, however, far smaller amounts of critical alloying elements—because GRAINAL Alloys replace these elements with respect to hardenability.

If you are having trouble getting steels with the hardenability you require, investigate boron steels today.

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(1) Use Kennametal cemented carbide . . .

(2) in tooling designed by our engineers who know carbides from the ground floor up . . .

(3) applied with the help of our field engineers whose aggregate experience is greater than that of any other carbide tool manufacturer.

This cure is working in thousands of shops—handling jobs which no other tools can do. But, even if you don't have a cutting headache, consider this important point:

Tooling that takes tough jobs in stride is the kind to use, also, on routine jobs where floor-to-floor time and overall cost-per-piece must be determined with accuracy, and maintained.

That tooling is Kennametal. Let us prove it in your shop. Kennametal Inc., Latrobe, Pa.

KENNAMETAL

CEMENTED CARBIDE TOOLING
THAT INCREASES PRODUCTIVITY

®

Atmospheres for Castings

(Continued from p. 118)

chunks of electrode carbon, and casting was done in a reducing atmosphere of carbon monoxide.

Today oxidizing conditions are more easily handled in the bronze foundry. But castings made under oxidizing conditions contain oxides and, on occasion, are subject to serious gas porosity, either submicroscopic, microscopic or visible. Handling metal under reducing conditions is difficult – but commercially possible – because of the susceptibility of the melt to dissolve hydrogen from water vapor and hydrocarbons. Melting can be accomplished by using massive carbon covers (broken electrode carbon with the fines removed) free of slag; removing even small quantities of slag that form; and preventing water, oil, and hydrocarbon vapor from coming in contact with the charge.

Certain operations, such as the two examples referred to, which demand high quality metal have successfully used reducing practices for some time.

CARL E. SWARTZ
Consulting Metallurgist

Against Use of Reducing Atmospheres

HAMPSTEAD, QUEBEC

The fact that Mr. Swartz, in a highly specialized foundry operation, gets more uniform results by using two furnaces in sequence, the first with an oxidizing atmosphere and the other reducing, is accepted; however, as the metal is first melted in an oxidizing atmosphere, it confirms my statement.

I should not like to advise the average foundry to revert to the use of a reducing atmosphere as a general procedure, notwithstanding the fact that we have a foundryman on the Pacific Coast who does use a reducing atmosphere followed by a dry air blast blown through the molten metal to remove the hydrogen absorbed.

As to the melting of copper for pure copper castings, undoubtedly this must include very special treatment – which will be found described in detail in my book "Cast Bronze".

H. J. ROAST
Bronze Foundry Consultant

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The design of gas carburizing trays and fixtures to obtain maximum service life requires a thorough knowledge and understanding of

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- effect of black body conditions of each specific loading.
- effect of square corners and small radii.
- effect of unequal sections.
- effect of cooling rates in the mold, the furnace, and the quench tank.
- plus a complete knowledge of foundry techniques to obtain the highest quality castings.

Hundreds of trays are being used by industries with unnecessary designed-in self-fatiguing stresses which are costing the consumer thousands of dollars per year through decreased service life.

If you are interested in lower heat-hour costs, call an **ACCOLOY ENGINEER** for an honest analysis of your problem. There is no obligation on your part.

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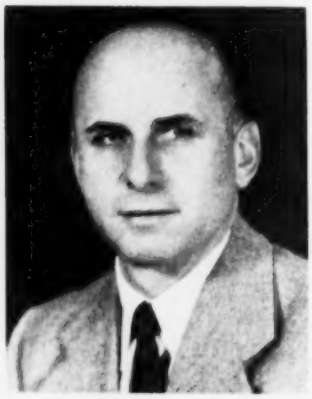
Personal Mention



Oscar T. Marzke

OSCAR THEODORE MARZKE, superintendent of the metallurgy division at the Naval Research Laboratory, Washington, D. C., has been named consultant to the director of research at NRL in the fields of chemistry, electricity, mechanics, and metallurgy. Dr. Marzke is also head of the metallurgy branch of the Office of Naval Research and will retain both positions while serving in his new capacity. A native of Lansing, Mich., Dr. Marzke received his undergraduate education at Michigan State College and obtained his Doctor of Science degree from Massachusetts Institute of Technology. During part of the time he was taking his graduate work, he served as a laboratory technician at the Naval Research Laboratory. From 1933 to 1946 he was a metallurgist with the American Steel & Wire Co., becoming works metallurgist at the Waukegan, Ill., plant in 1942. He joined the Laboratory in 1946 as superintendent of the metallurgy division. Dr. Marzke is a member of the American Institute of Mining and Metallurgical Engineers, American Welding Society, Tau Beta Pi, the British Institute of Metals and the British Iron and Steel Institute. He is the author of several papers in the field of metallurgy, his chief scientific interest being in the relation between structure and behavior of metals.

Alexander Gobus

ALEXANDER GOBUS has joined North American Philips Co., Inc., Mount Vernon, N. Y., as head of their new nondestructive testing department, set up to handle research developments in the industrial X-ray field. Mr. Gobus was vice-president, chief metallurgist and director of nondestructive testing at Sam Tour & Co. from 1943 to 1953. Prior to that he was with Lucius Pitkin, Inc., Interborough Rapid Transit Co., New York, American Car and Foundry Co., and Doehler Die Casting Co. Mr. Gobus is an author and lecturer as well as a consultant on matters pertaining to all phases of nondestructive testing. He has held and still holds many important committee posts with various technical societies. He is a member of the American Welding Society, American Institute of Mining and Metallurgical Engineers, American Industrial Hygiene Association, American Society for Testing Materials, Society for Nondestructive Testing, and the Metals Science Club of New York. He is the ASTM representative to the Committee on Standard Radiographs of the International Institute of Welding. He was a member of the American Standards Association group that formulated protection against radiation from the use of radium, and is now the AWS representative to the group charged with modernizing the present code for X-ray protection.

Samuel A. Wenk has been named to supervise nondestructive testing research at Battelle Memorial Institute, Columbus, Ohio. A member of the research staff for the past three years, Mr. Wenk joined Battelle in 1948. Prior to that he was chief metallurgist for Bowser, Inc., Fostoria, Ohio. During World War II he served for five years in the Ordnance Dept., attaining the rank of lieutenant colonel. While on active duty he was chief of inspection for the Pittsburgh Ordnance District and chief production engineer for heavy caliber ammunition in the Office of Chief of Ordnance. A graduate of Virginia Polytechnic Institute, Mr. Wenk has his B.S. in metallurgical engineering. His early career was that of metallurgist with steel mills in the Pittsburgh area.

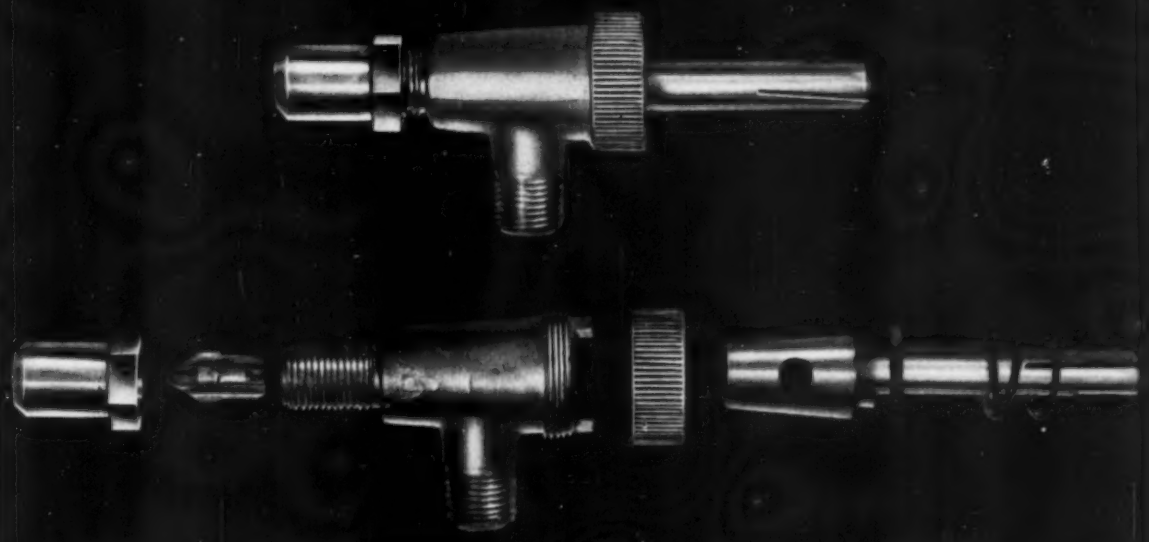
John R. Freeman, Jr., has been appointed vice-president of metallurgy and research at American Brass Co., New York. In his new position he will be responsible for all metallurgical research projects at all of the company's branches throughout the nation. A graduate of Massachusetts Institute of Technology, he served for 15 years in the National Bureau of Standards, division of metallurgy, and was assistant chief of the division from 1928 to 1930. He then joined the technical department of American Brass and in 1934 was named assistant manager of the department. In 1938 he was made technical manager of the company.

I. Joseph Stubinski has been promoted to the post of secretary of Keystone Drawn Steel Co., Spring City, Pa. He joined Keystone in 1934 as an inventory control clerk and during World War II was in charge of the controlled materials plan and production planning for the company. In 1951 he was made assistant secretary.

James L. Wyatt received a D.Sc. degree in metallurgy from Massachusetts Institute of Technology last February and has accepted a position with Horizons, Inc., Cleveland, as assistant to the technical manager. He was formerly employed by Titanium Div., National Lead Co., Sayreville, N. J.

LINCOLN FINDS

Brass is Best



Kitchen range burner valve by Lincoln Brass Works, Inc., Detroit 16, Mich. Two different brasses are used in this valve, which is entirely of brass except for the washer and spring. Lincoln also makes valves for heaters and furnaces; flow, drain and shut-off valves for gasoline lines; shut-off valves for agricultural sprayers, and a wide variety of tube and pipe fittings, all entirely or chiefly of free-cutting brass rod and free-machining brass forgings.

Mr. D. E. DuPerow, Vice-President of Lincoln Brass Works, Inc., recently said: "Thirty-six years of brass use by Lincoln and complete acceptance by the trade is the best reason I can think of for brass superiority. If there had been any material better for our purpose, less expensive to fabricate, and more desirable to our customers, we would be using it now."

Brass has many desirable characteristics. Here are five of them that are important in Lincoln valves and fittings: 1, corrosion resistance, which means no plating is required. 2, high speed precision machining for high output, lower costs. 3, sound, non-porous structure of rod and forgings. 4, smooth performance; brass holds lubricants. 5, customer satisfaction; gas range burner valves pass the cycling test of being raised to 425°F. and back to room temperature a minimum of 10,000 times without seizure, loss of free operation, or leakage.

There are many other items besides valves that can profitably make use of the fine qualities of Revere Brass. The Revere Technical Advisory Service will gladly cooperate with manufacturers on the selection of the correct brass and its fabrication. Just call the nearest Revere Sales Office; see your telephone directory. Or write direct.

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AMBLER ACP PENNA.

Technical Service Data Sheet
Subject: RUST PROOFING WITH PERMADINE®

Steel parts that have been Permadized and then "sealed" with a rust-preventive oil such as "Granoleum" are effectively protected from rust. And, if the oiled "Permadine" coating should be damaged, rusting will not spread beyond the area of exposure.

Note: Automotive and other rubbing parts subject to friction are usually given "Thermoil-Granodine" manganese-iron phosphate coatings for both wear-resistance and protection from corrosion.

DATA ON THE "PERMADINE" COATING	
Type of coating	Zinc phosphate
Object of coating	Rust and corrosion prevention
Typical products treated	Nuts, bolts, screws, hardware items, tools, guns, cartridge clips, fire control instruments, metallic belt links, steel aircraft parts, certain steel projectiles and many other components
Government Specifications	U.S.A. 57-0-2C; Type II, Class B MIL-C-16232, Type II U.S.A. 51-70-1, Finish 22.02, Class B AN-F-20 Navy Aeronautical M-364 JAN-L-548
Scale of production	Large or small volume; large or small work
Method of application	Dip Barrel tumbling, racked or basketed work
Equipment notes	Immersion tanks of suitable capacity. Cleaning and rinsing stages can be of mild steel. Coating stage can be of heavy mild steel or stainless steel.
Chemicals required	"Permadine" No. 1
Pre-cleaning methods	Any common degreasing method can be used. Alkali cleaning ("Ridosol"), Acid cleaning ("Deoxidine"), Emulsion-alkali cleaning ("Ridosol" - "Ridoline"); vapor degreasing, solvent wiping, etc., are examples. Acid cleaning may need to follow other cleaning methods if rust or scale is present.
Bath Temperature	190° - 205°F.
Coating time	20 - 40 minutes
Coating weight range	1000 - 4000 mgs. per sq. ft.
Technical Service Data Sheets	No. 7-20-1-2 T.M. No. 5

CHEMICALS ACP PROCESSES

WRITE FOR FURTHER INFORMATION ON "PERMADINE"
AND YOUR OWN METAL PROTECTION PROBLEMS

CHEMICALS ACP PROCESSES

Personals

Raymond L. Smith, senior research metallurgist in the solid state physics division of Franklin Institute, Philadelphia, has been given charge of the division's new metallurgy section. He is a graduate of the University of Pennsylvania where he has been active in metallurgical research.

E. S. Hudson has been transferred from Dallas to Houston and promoted from contact metallurgist to assistant vice-president of the Earle M. Jorgensen Co. He is a former chairman of the Golden Gate Chapter.

William E. Kuhn, formerly senior metallurgist with the Titanium Alloy Mfg. Div., National Lead Co., is now employed by the research and development division, Carborundum Co., Niagara Falls, N. Y., as research engineer responsible for research and development of zirconium.

Norman A. Parlee has resigned his position as assistant director of metallurgy at Dominion Steel & Coal Corp., Canada, to become associate professor of metallurgy at Purdue University. He obtained his Ph.D. degree from McGill University.

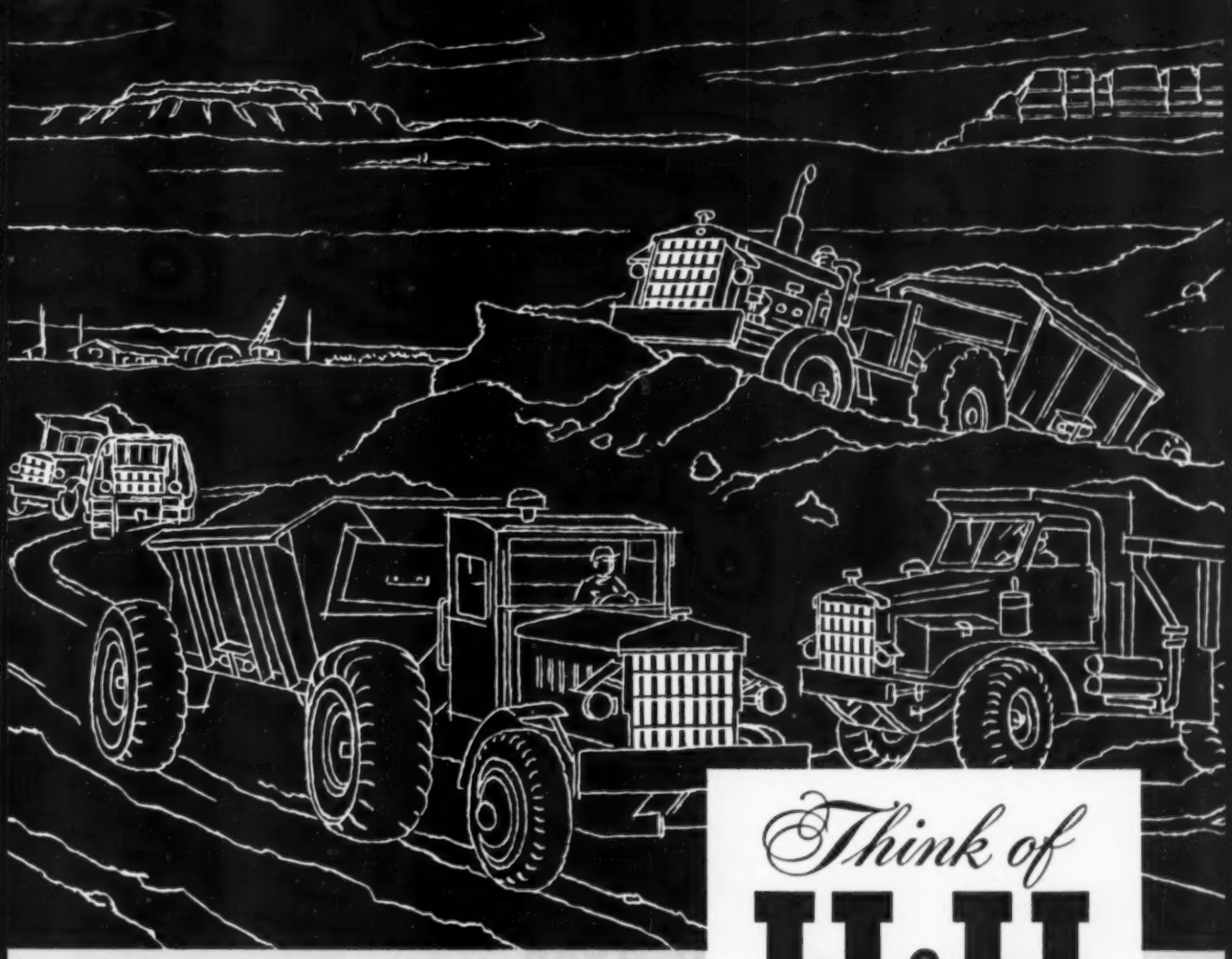
Raymond F. Fritz has left Hotpoint Co., subsidiary of General Electric Co., after four years as assistant metallurgist to become chief metallurgist of Amgears, Inc., Chicago, owned by Hupp Corp.

Robert Lowrie, formerly aeronautical research scientist with the National Advisory Commission for Aeronautics, has accepted a position as research metallurgist with Union Carbide & Carbon Research Labs., Inc., Niagara Falls, N. Y.

Keith S. James is now heat treater for Schwien Engineering Co., Van Nuys, Calif.

Alex R. Van Dyke has left his position as metallurgist with Detroit Controls Div., American Radiator and Standard Sanitary Corp., to accept a similar position with Lyon, Inc., Detroit, in the ordnance development division.

Andrew P. King, formerly sales engineer with Tungsten Alloy Mfg. Co., Newark, N. J., is now general sales manager in the firm.



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THE SAME H & H LOCKSEAM TUBING that cools your car's engine, also cools many types of truck, tractor and stationary engines which provide the power for heavy construction work. Often subjected to years of gruelling use under extreme climatic conditions, these engines offer additional proof that H & H brass and copper tubing and fabricated parts are used *wherever* quality and long life count. No matter what you manufacture, if your operation calls for tubing that will *last*, call your nearby H & H representative *first*.

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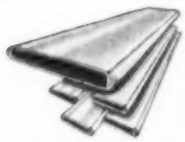
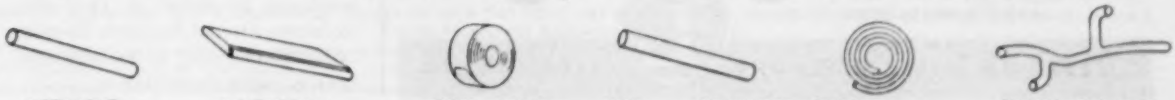
Originators and sole makers of "Metalflo" — the economy tubing



LOCKSEAM TUBING*

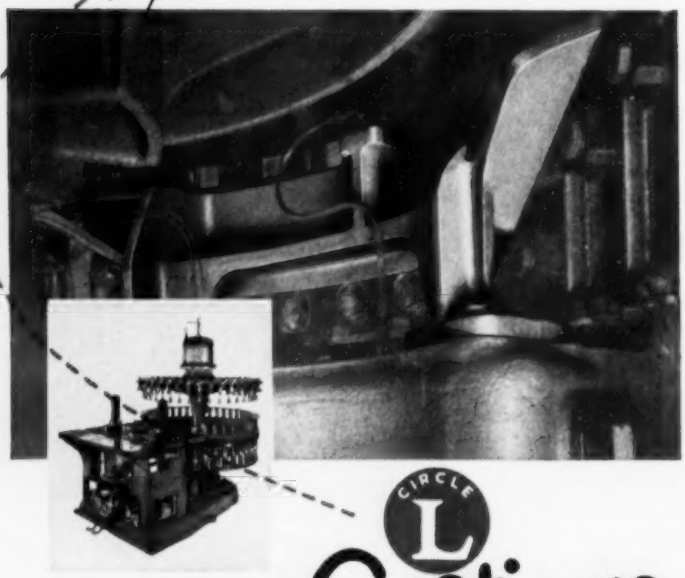
Available in round or oval shapes, in a wide range of metals. Precision cut to random or specified lengths in sizes to meet requirements of heating and cooling field. Solder coated on outside or both sides.

*Blueprint of size ranges and standard tubes furnished upon request.



METALFLO LOCKSEAM COIL STRIP AND SEAMLESS TUBING TUBULAR PARTS

CALLING A FIGURE IN A bottle dance



LEBANON Castings ARE AT WORK

EVERYONE is fascinated by the sound and action of modern bottling machinery at work. It's the cams that "call the figures in this bottle dance"! And these cams have to be tough.

In Crown Cork & Seal Company's CEM 40 bottling machine, illustrated above, the sturdy cam is a Lebanon CIRCLE (L) special alloy steel casting. The efficiency of this machine that fills and caps many millions of soft drink bottles a year, is due in part, to the special wear and endurance properties built into the Lebanon Alloy Steel employed in casting the cam. The cam illustrated must hold its form and size, must keep wear to a minimum thereby eliminating expensive machine down-time.

Wherever castings are required, it's sound practice to use only the highest quality. Those bearing the CIRCLE (L) trade mark are high quality products of true Lebanon craftsmanship.

You should see . . .
STEEL WITH A THOUSAND QUALITIES

This 37 min., 16 mm. full color sound film showing the making of steel castings from blueprint to end use should be shown to your staff. For information write: Dept. H, Lebanon Steel Foundry, Lebanon, Pa.

LEBANON Castings
CARBON, SPECIAL ALLOY AND STAINLESS STEEL
LEBANON STEEL FOUNDRY LEBANON, PA.

Personals

Leo M. Elijah has accepted a position as an assistant metallurgical engineer at Canadair, Ltd., Montreal, in the engineering control division. He recently received an M.S. degree in metallurgical engineering from the University of Wisconsin and a diploma in foundry technology from the National Foundry College, England.

David L. McBride, formerly staff metallurgist, Minerals and Metals Advisory Board, National Research Council, Washington, D. C., has been appointed supervisor, research associates, research and development branch of the U. S. Steel Corp., Pittsburgh. He will coordinate research and development programs in steelmaking and processing.

U. R. Jaeger has become associated with Superior Magnesium Castings Division of Superior Bearing Bronze Co., Inc., Brooklyn, N. Y., as sales manager.

L. B. Stark, formerly in charge of the manufacturing development group, manufacturing engineering department, Consolidated Vultee Aircraft Corp., San Diego (Calif.) Division, has accepted a position as assistant to the president of Zephyr Mfg. Co., Inglewood, Calif. He will be responsible for the direction of production and sales activities.

Harry L. Jenter has been promoted to district manager of operations for the Cleveland District of American Steel & Wire Div., U. S. Steel Corp. He was formerly assistant district manager, a position to which he had been appointed last November.

A. F. Wiest has been placed in charge of all manufacturing operations for Carpenter Steel Co.'s Alloy Tube Division at Union, N. J. He has been with the company since 1929, having been previously associated with the Newark Tube Co. and the Chrome Alloy Tube Co.

James E. Johnson completed requirements for a Ph.D. degree in mechanical engineering at California Institute of Technology and is now employed by Rohm & Haas Co., Redstone Arsenal Research Division, at Huntsville, Ala., as research engineer in rocket development.

No. 118 of a Series of Typical Installations

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THE BEST INDUSTRIAL FURNACES MADE

HOW SUNBEAM INDUSTRIAL FURNACES MEET THE DEMANDS ON THE PRODUCTION FRONT

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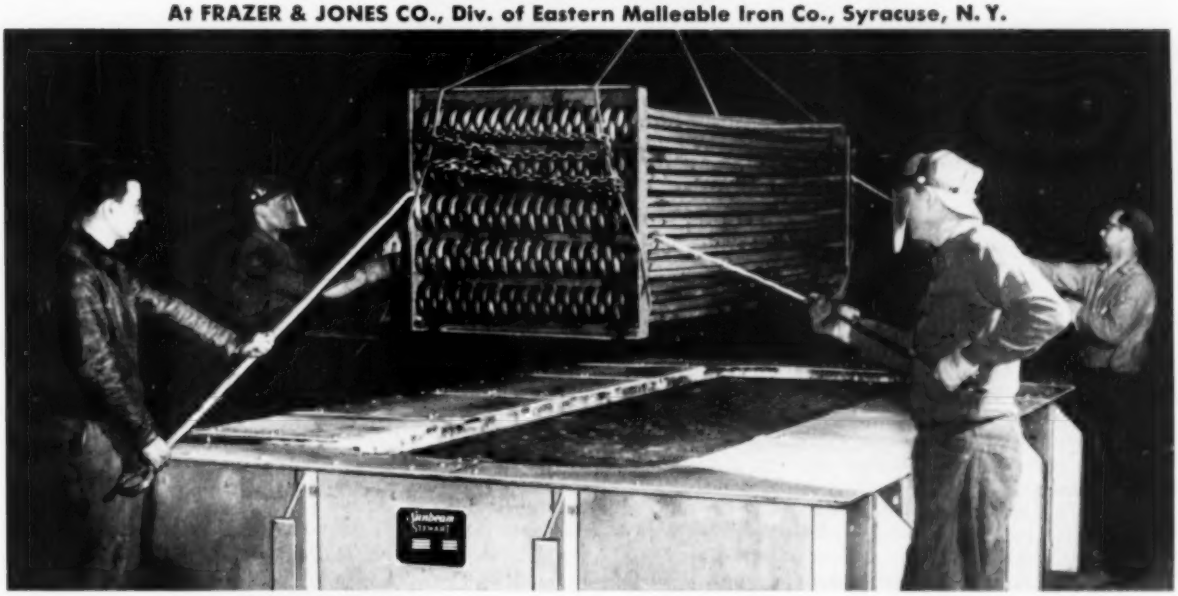
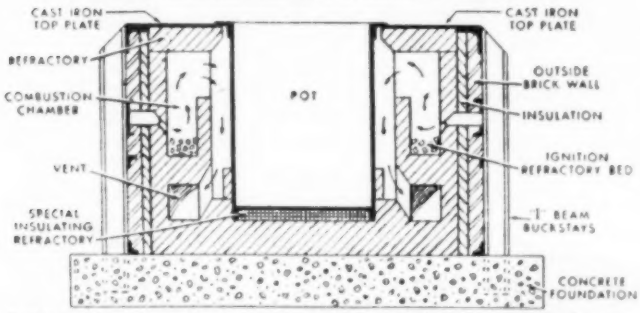
At FRAZER & JONES CO., Div. of Eastern Malleable Iron Co., Syracuse, N. Y.



SUNBEAM STEWART

INDIRECT HIGH-SIDE FIRED (Gas) GALVANIZING SETTING



Fuel is completely burned in a separate combustion chamber. Hot products of combustion flow evenly up over a dividing baffle wall to the top section of the pot and then down the side to exhaust vents.

A variety of work is processed in the two Sunbeam Stewart Galvanizing furnaces in use at Frazer & Jones. Besides their own castings, they galvanize various products for outside companies, including special pipe-fittings, pole-line hardware, castings, naval weldments, forgings, etc. Kettles have been designed large enough so that the work can be easily handled in dipping, and can be completely dipped without disturbing the cool bottom area of the kettle where the dross collects.

Improved design and correct engineering have made Sunbeam Stewart the leader for galvanizing equipment. Quality of work and low cost of maintenance and operation are key factors in Sunbeam Stewart's design which have proved their worth year after year. Users report dross loss as low as 5% and kettle life up to six years. If galvanizing is important in your manufacturing process, it will pay to consult Sunbeam Stewart. Designs are available for small or large production. We will be glad to submit ideas on how you can get more economical operation.

IF YOU ARE CONSIDERING DEFENSE WORK CALL SUNBEAM. Designs are available for heat treating the following materiel:

SHELLS: 57MM; 75MM; 90MM; 105MM; 120MM; 155MM; 3", 5", 6", 8" Navy Shells (Harden, Quench and Draw).

FORGINGS: Rotary Hearth and Pusher-type Forging Furnaces.

ARMOR PIERCING SHOT (Harden, Quench and Draw).

CARTRIDGE CASES (Anneal, Stress Relieve).

MACHINE GUN CLIPS (Harden, Quench and Draw).

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A letter, wire or 'phone call will promptly bring you information and details on SUNBEAM industrial furnaces, either units for which plans are now ready or units especially designed to meet your needs. Or, if you prefer, a SUNBEAM engineer will be glad to call and discuss your heat treating problems with you.

HOW TO HAVE YOUR CAKE

. . . AND *Eat* IT, TOO

There are certain disadvantages to ordinary annealed abrasives: they have a low cleaning speed compared to chilled iron shot and grit, because the cutting action is comparatively light; and the presence of graphitic carbon leaves an undesirable graphite deposit on the work being processed that may interfere with subsequent finishing operations such as enameling, galvanizing, bonding, etc. On the other hand, annealed abrasives enjoy the tremendous advantages of longer abrasive life and much lower maintenance costs. The question is: how to enjoy the advantages without suffering from the disadvantages —how to have your cake and eat it, too.

Permabrasive annealed abrasives retain some of the hard iron carbides (that do the rapid cutting) in small, spheroidal form, with the result that you get a cleaning efficiency not usually associated with annealed abrasives; Permabrasive is made in three distinct hardness ranges with a narrow range of hardness in each, which makes it possible to shift from one grade to another as production problems demand.

You may be able to buy other brands of annealed iron abrasives for $10 to $20 less per ton, yet we'll guarantee your cleaning costs with Permabrasive to be LOWER, regardless of the price you are now paying. Write, wire or phone the nearest Hickman, Williams office and enjoy the advantages of annealed abrasives without the disadvantages.

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*Licensed under U. S. Patent No. 2184926, U. S. Application No. 619602

Personals

Edward N. Ryan, formerly a sales engineer in the New York office of Crucible Steel Co. of America, has been appointed assistant manager of that branch. After joining Crucible Steel in 1935, he was employed at the company's Altha Works at Harrison, N. J. He held the posts of metallurgist and tool supervisor of ordnance works. Transferred in 1946, Mr. Ryan became a member of the New York general office sales staff. In 1948 he was assigned to the New York branch at Harrison, N. J., as a sales engineer, a position he held until his latest appointment.

Holcroft & Co., Detroit, announces that **H. O. Bennett** is now their representative in Indiana and Kentucky, and **Louis A. Lange** is representative in Wisconsin.

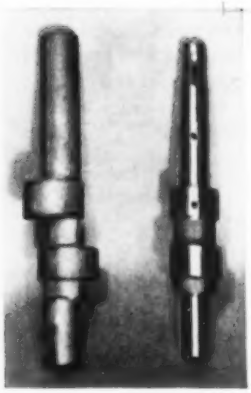
S. C. Das Guptas has left the post of research associate at Massachusetts Institute of Technology and has been appointed assistant professor of metallurgy in Bengal Engineering College, W. Bengal, India.

M. E. Hackstedde, formerly sales engineer for the Tocco Division of Ohio Crankshaft Co., has been appointed manager of the production heat division of GECO, Inc., one of the affiliates of the General Engineering Co. He will be at the Cleveland headquarters and will be responsible for the sales and manufacturing of the company's GECO line of induction heating equipment.

Kent R. Van Horn, director of research of Aluminum Research Laboratories, Aluminum Co. of America, delivered the feature lecture before the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers at the Institute's annual meeting in Los Angeles in February. Dr. Van Horn becomes the 33rd distinguished metallurgist to be honored by appointment to the IMD Lectureship since its origin in 1921. In his lecture, he discussed residual stress in metals.

Frank R. Romeo has been appointed superintendent of the roll hardening department of The Midvale Co., Philadelphia. He came to the company in 1949 having been graduated in metallurgy from the University of Notre Dame the previous year.

This furnace helps make ice cubes and cool breezes



Raw casting and finished crankshaft of York hermetic compressor. Cast from metal melted in Detroit furnace.

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Personals

Robert L. Fitzsimons has been appointed metallurgical engineer for Jessop Steel Co., Washington, Pa. Prior to his new appointment, Mr. Fitzsimons was employed for 30 years by the E. C. Atkins Co., Indianapolis, and was appointed chief metallurgist of that concern in 1950.

Jack D. Ramsdell has accepted a position as metallurgist in the research department of the Naval Ordnance Test Station, China Lake, Calif.

Kenneth M. Ford has been appointed assistant manager of "OSCO" Steel Co., Detroit branch. He had been sales manager of the Cleveland branch prior to this appointment. Before coming with "OSCO", Mr. Ford was connected with the rustless iron and steel division of Armco Steel Corp.

James M. Lommel has been elected president of the Illinois Institute of Technology chapter of Tau Beta Pi, national engineering honor society, for the second semester of the 1952-53 academic year.

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H. C. Schlaupitz has been appointed director of research at R. Wallace and Sons Mfg. Co., Wallingford, Conn. Previous to this appointment he was research engineer at the company since 1946.

P. E. Mehta has opened offices as a consulting engineer in Calcutta, India, dealing with geology, mining and metallurgy.

Irving B. Bishop, formerly field metallurgist for the South Chicago plant, Republic Steel Corp., is now fulfilling similar duties at the Union Drawn Steel Div. of Republic.

Edwin J. Mets has resigned his position with Chrysler Corp. to accept a position as development metallurgist with General Electric Co., Pittsfield, Mass.

C. W. Jordan, Jr., has accepted a position as metallurgist with the Shakeproof Div., Illinois Tool Co., at the St. Charles Rd. plant in Elgin, Ill.

Hugh P. Gibbons, formerly with Standard Foundry, Cadillac, Mich., is now plant superintendent of Cannon-Muskegon Corp., Muskegon, Mich.

G. O. Loach has been appointed assistant manager of the Welland plant of Electro Metallurgical Co. of Canada, Ltd. He has been with the company since 1945 and was elected a director and vice-president in 1951.

R. L. Reed has been appointed district manager of the Detroit office of Electro Metallurgical Co., a division of Union Carbide and Carbon Corp. He joined the Chicago office of Electromet in 1946 and two years later was transferred to the Detroit district where he has been located for the past five years.

John T. Milek is now director of research and development at Arthur C. Withrow Co., Maywood, Calif. He was formerly with Hughes Aircraft Co., Culver City, Calif.

Herbert F. Krohn, formerly assistant supervisor of laboratories, Bethlehem (Pa.) Plant, Bethlehem Steel Co., is now employed in a technical sales capacity handling products of the Bethlehem Plant in the Chicago district. Mr. Krohn was secretary-treasurer of the Lehigh Valley Chapter during 1951-52 and 1952-53 (to Jan. 1).

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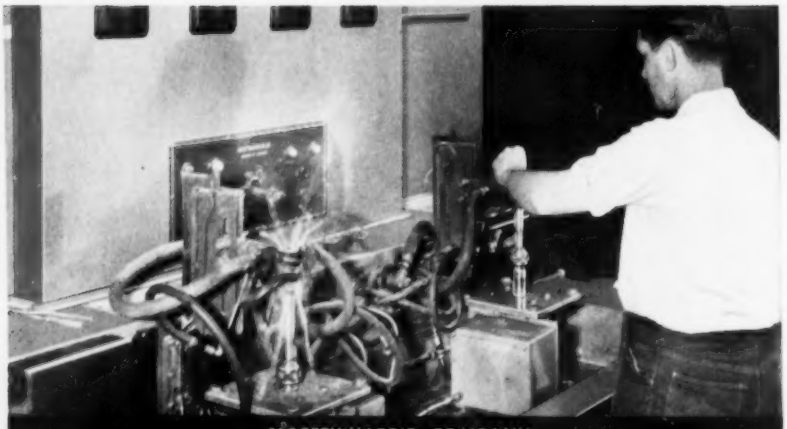

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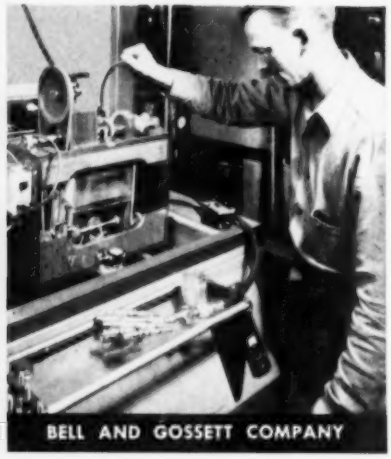

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J-02262

Personals

R. J. Leary, formerly development metallurgist at Duquesne Works, U. S. Steel Corp., has been appointed extractive metallurgist in the pyrometallurgy branch of the Bureau of Mines, Pittsburgh. He is supervisor of openhearth steelmaking research projects being conducted in the Bureau's three-ton experimental openhearth furnace.

R. C. Smith, who has resigned as vice-president in charge of manufacturing and engineering development at Eversharp, Inc., has joined the firm of Knowles Associates, New York, chemical, metallurgical and mechanical engineers, as a partner. Mr. Smith was in charge of eastern district operations for H. K. Ferguson Co. prior to his association with Eversharp.

Jay DeEulis, former engineering editor of *Steel*, has joined Carboloy Dept., General Electric Co., Detroit, as technical editor of the news bureau. He was associated with Penton Publishing Co., Cleveland, for 15 years.

A. E. Broady has been appointed representative in the Cleveland district for American Cyanamid Co.'s metal chemicals section. A member of American Cyanamid's staff since 1949, he was formerly eastern regional representative.

C. W. Barnthouse, Jr., has been appointed assistant district manager of the Los Angeles sales office of Latrobe Steel Co., Latrobe, Pa. He was transferred to the West Coast offices of Latrobe in 1950 and since that time has engaged in both sales and metallurgical service work in the Los Angeles area.

M. M. Mossman has been appointed agent in the northwestern states for Damascus Tube Co., Greenville, Pa., maintaining an office at Seattle, Wash. His territory will cover Washington, Oregon and northern Idaho.

Edward H. Platz, Jr., manager of alloy sales, Lebanon Steel Foundry, Lebanon, Pa., has returned to his post. He had been on leave of absence to take up his governmental duties serving the National Production Authority as nickel specialist, iron and steel division.

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Boron Additions by Reduction of Boron Oxide*

THE BRITISH OPINION on the methods of adding boron to steel and its metallurgical effects is given in this paper, and a method for incorporating boron by reduction of the element from slags containing boron is described.

At the present time most boron additions are made by adding ferroboron or the complex alloys containing boron, such as grainal, silcaz and carbotam. Observations made on induction furnace heats indicated that the steel melts were picking up this element from the presence of borates in the linings. In addition, the use of a wash slag containing Howlite ($4CaO \cdot 2SiO_2 \cdot 5B_2O_3 \cdot 5H_2O$) for coating the linings of arc furnaces prior to shut-down periods caused the slags on subsequent heats to contain considerable amounts of boric oxide. The steels made in the furnaces containing boron in the lining all showed varying amounts of this element.

Tests run on heats from arc furnaces showed no boron in the steel when no Howlite was added to the charge; 0.0006% soluble boron and 0.0010% insoluble boron on heats treated with 18 lb. of Howlite per 1000 lb. of slag; and 0.0014% soluble boron, 0.0017% insoluble boron on heats treated with 36 lb. of Howlite per 1000 lb. of slag. This work showed clearly that boron oxides in the slags were introducing boron into the steel and repeated trials indicated a close correlation between the amount of boron in the slag and its final content in the steel.

Experience has shown that the condition in which boron is present in steel has a marked effect on the metallurgical influence that this element has on the hardenability of steel. The small amounts of boron present (usually under 0.004%) make analysis difficult, but it has been found that when the acid-soluble fraction of the boron is high the hardenability effect is also greatest. Speculation as to the form of distribution of boron in steel leads to the conclusion that it exists as alloy, oxide, nitride, and in other forms. It has also been assumed that the oxide and nitride remain insoluble on analysis. This opinion is supported by the fact that boron additions to

(Continued on p. 136)

*Digest of "Addition of Boron to Steel by Reduction From Boron Oxide", by G. E. Speight, *Journal* of the Iron and Steel Institute, Vol. 171, June 1952, p. 147-153.

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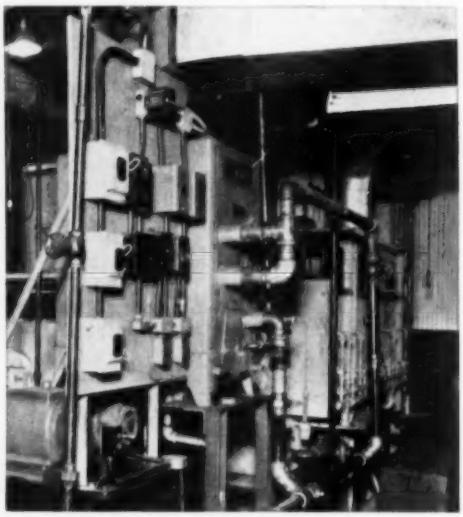

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Boron Additions by Reduction of Boron Oxide

(Continued from p. 134)

steel are ineffective unless the heat is treated with additions of aluminum, titanium or zirconium before boron is introduced. The mode of its occurrence in steel is discussed at length in the paper.

Based on these observations and theories, a series of heats were melted in a high-frequency induction furnace; the basic analysis of the steel was 0.14% carbon, 0.40% Mn, 0.20% Si, 0.45% Mo, and a sillimanite crucible was used. After melting and making the normal additions, 6 g. of aluminum and 12 g. of ferrotitanium were added to the 8000-g. melts for deoxidation and stabilizing the nitrogen. The melt was covered with 160 g. of slag mixture containing CaO and 1, 2, 5, 10, or 20% borax. After adjusting the metal temperature to 1600° C. (2910° F.), the charge was held for 5 min. and then the metal was cast. Analyses of the resulting metal and slags showed a linear relationship between the boron in the steel and the borax in the slag as tabulated below:

Total Boron in Steel	Borax in Slag
0.0%	0.0%
0.0002	1.0
0.0007	2.0
0.0016	5.0
0.0029	10.0
0.0057	20.0

Some interesting results were obtained from this series of heats. Even though the acid-soluble boron exceeded 0.0015% in heats treated with slags containing over 10% borax, the hardenability tests were quite disappointing in that the influence of boron on this property was not evident. Spectrographic examination of these heats showed no residual aluminum or titanium in the metal; the authors concluded that these elements, added before the borax slag treatment, had been eliminated by oxidation during the slag treatment. Even with 20% borax in the slag and 0.003% acid-soluble boron in the steel the hardenability tests were unsatisfactory.

It was therefore obvious that deoxidation and nitrogen stabilization treatments after the slag-reaction period were necessary. Several heats were made with additions of aluminum and ferrotitanium before and after the slag reactions. Under these conditions practically all the boron in the steel then occurred in the

(Continued on p. 138)

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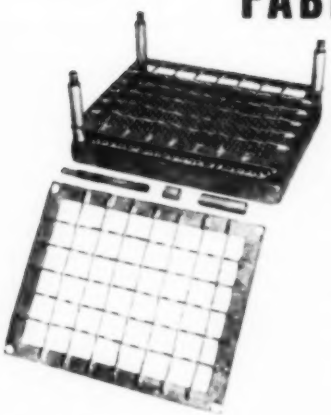

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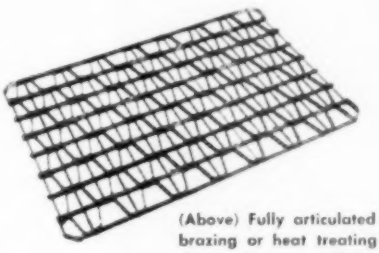

(Above) Inconel basket assembly for nitriding. Only required baskets need be used for less than capacity operation . . . reducing furnace load.

(Below) Inconel muffle for hardening roller bearing parts in gas furnace, with propane and cracked ammonia atmosphere. Flange faces machined for gas-tight service at 1600° F.

(Above) Fully articulated "Serpentine" brazing or heat treating tray, retains shape. Heavy or light, any width, length, depth. Many uses at lowest hourly cost.

(Right) Stainless drop-bottom pit furnace basket for quality, uniform heat treat. Saves seconds between heat and quench.

(Left) Alloy carburizing basket. Loose joints expand under heat. Rugged, flexible construction resists abuse.

(Right) Sectional lift post carburizing fixture. Most versatile for handling variety of parts. Each loaded grid quenched separately, if desired.

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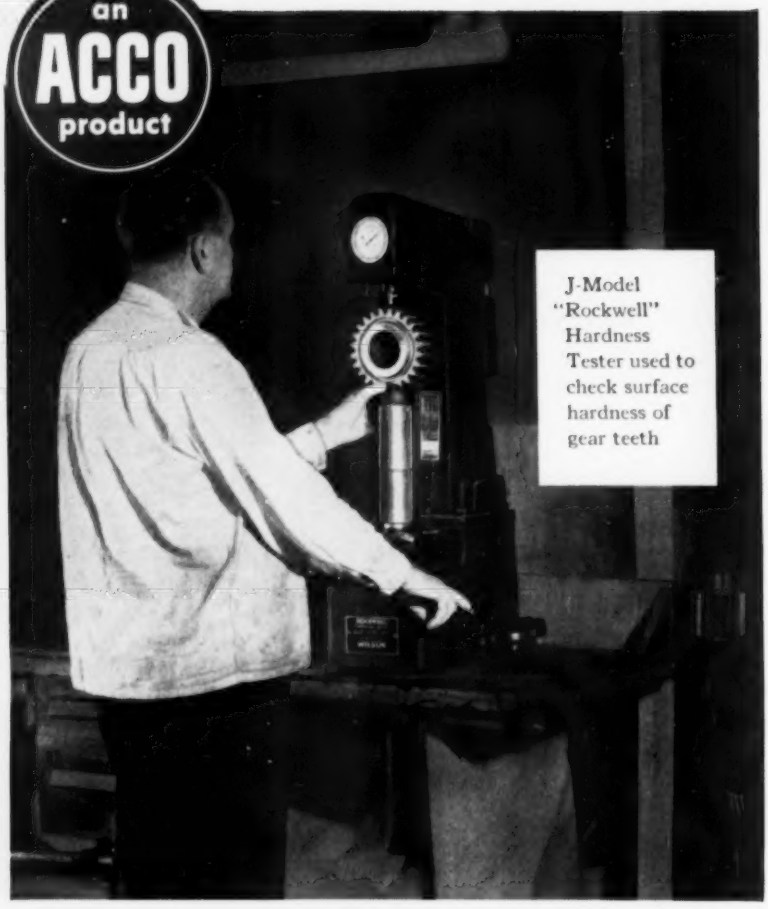

J-Model "Rockwell" Hardness Tester used to check surface hardness of gear teeth

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Boron Additions by Reduction of Boron Oxide

(Continued from p. 136)

acid-soluble form. All hardenability tests on these heats were satisfactory, and the yield of total boron in the steel increased to 0.0089%; this represented 60% better recovery of boron over the heats not treated with aluminum and titanium.

Additional experimental heats were made in which the 8000-g. melt was treated with 6 g. of aluminum before the slag treatment, and then with 6 g. of aluminum and 12 g. of ferrotitanium. These heats showed satisfactory hardenability and a high amount of acid-soluble boron. Determination of the boron partition between the slag and metal in a slag containing about 1.5% B_2O_3 indicated a ratio of B_2O_3 to B of approximately 300.

As a result of this investigation, the author makes recommendations as to the procedure for making boron steels in the openhearth, electric arc furnace and basic induction furnace. He makes no mention of the possible high nitrogen content of arc-furnace melts, or of the well-known difficulty of making uniform boron steels in the arc furnace.

E. C. WRIGHT

American Iron and Steelmaking Practices Compared With British*

CHAPTER 8

THE FOLLOWING practices have to some degree influenced the greater productivity of the American iron and steel industry: *(a)* Manning is reduced to a minimum; *(b)* machines and mechanical aids are much used, either to economize in labor or to speed working; *(c)* relief men are employed to enable mills to roll greater tonnages per shift; and *(d)* rotating working schedules on a 40-hr. week basis facilitates the working of rolling mills up to twenty shifts per week.

In addition, blast furnace plants, openhearth shops and primary mills work 52 weeks a year. Holidays are

(Continued on p. 140)

*Concluding part of the digest of the Productivity Report, "Iron and Steel", June 1952, 147 p., published by the Anglo-American Council on Productivity. Available from Office of Technical Services, Dept. of Commerce, Washington, D. C. Price on application.

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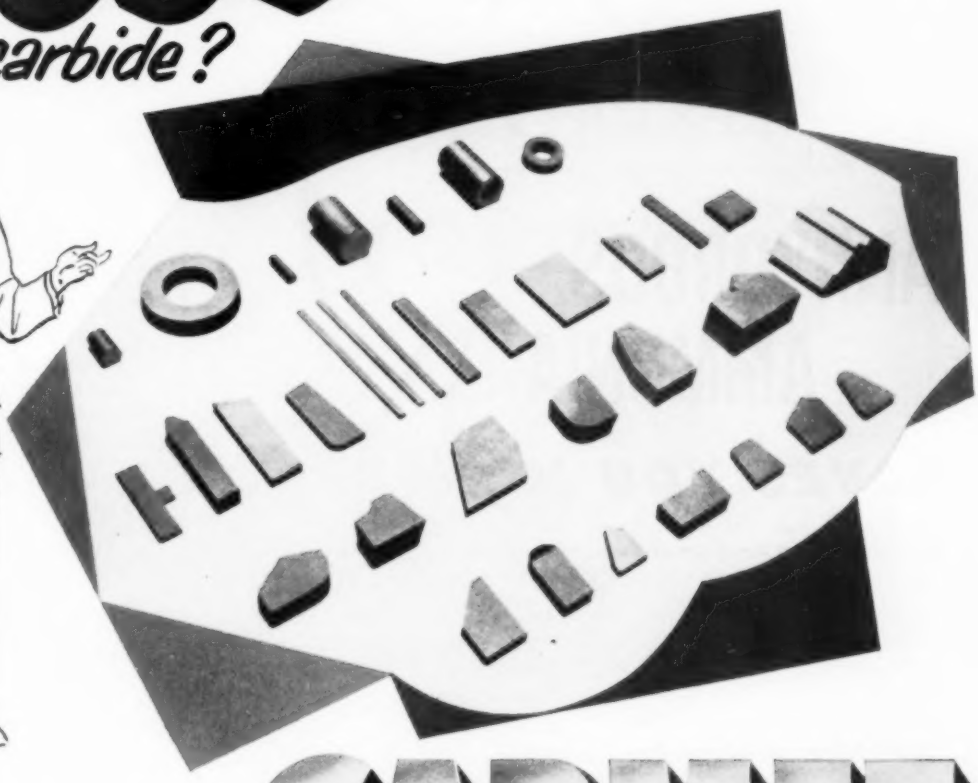

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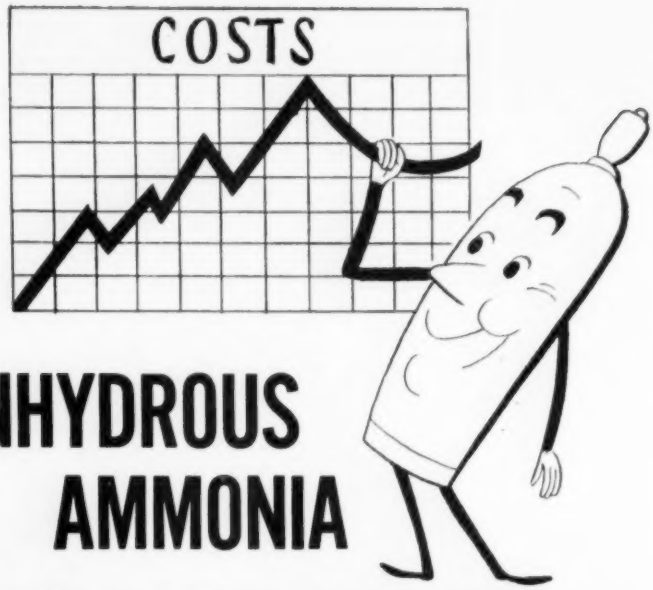

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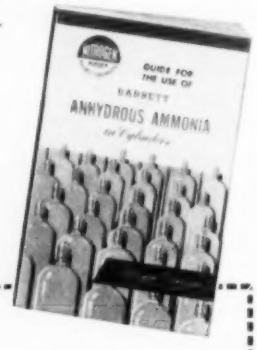
Write for full information on how Barrett® Brand Anhydrous Ammonia can save you money. The advice and help of our technical men are available to you without charge.



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CITY _____ STATE _____

Steelmaking Practices Compared With British

(Continued from p. 138)

taken in relays. Maintenance standing times for rolling mills are staggered over the week, and it is thus possible to make the most economical and efficient use of repair men.

Job evaluation for determining wage standards has been applied successfully and the number of grievances has been reduced. Production-bonus schemes have been applied where they are a positive encouragement to greater effort.

CHAPTER 9

British steelworks are much smaller than American, and this is the most important factor limiting increased efficiency and productivity.

All integrated steelworks should aim at a standard of size of 750,000 to 1,000,000 ingot tons per year; in some cases a larger works is advisable. Such works would permit reasonably high-capacity units of plant to be incorporated and would at the same time have a high degree of flexibility and integration.

Cold metal works can be "up to standard" if their capacity is not less than 300,000 tons per year for merchant and special products, and 500,000 tons per year for heavy steel products. It is suggested that steelworks in Britain should be expanded to take in more finishing processes.

Many improvements in the layout details of British works are possible, even within existing limitations. Increased efficiency of internal transport can be obtained through the use of radio communications. More seagoing ore vessels should be built to meet the likely demands for imported ore during the next ten years.

The cost of rail transport in Britain represents 10% of the cost of steel, despite the short hauls. The apparent low productivity both of labor and of rolling stock should be examined, especially with the object of increasing hopper-car and train loads above their present low values. British railways should be allowed a higher rate of capital expenditure for re-equipment. Cooperative studies between the railways and the users are also necessary to improve the performance of the terminal handling facilities.

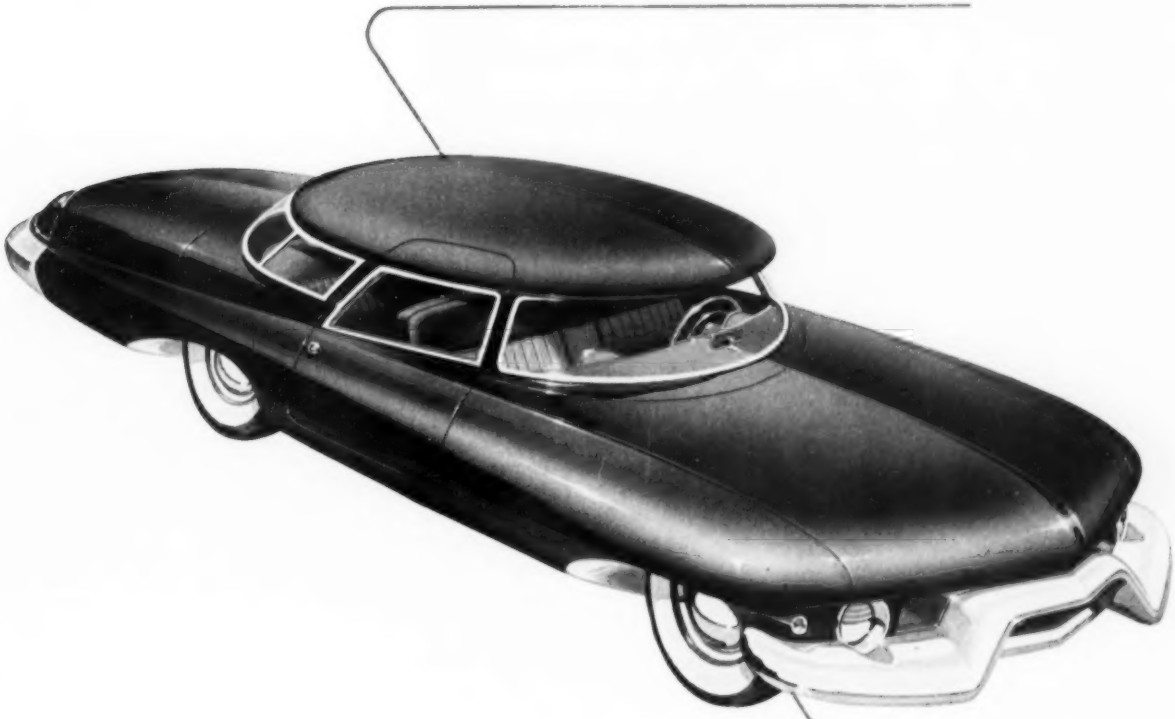
Road transport, internal and external, can play an important part in the handling of materials and products for general works, and

(Continued on p. 142)

Specify N·A·X HIGH-TENSILE STEEL for **Lighter Weight**

Longer Life

with Economy



N-A-X HIGH-TENSILE, with its 50 percent greater strength than that of mild carbon steel, means that thinner sections can be used . . . resulting in lighter weight of products. Because it is an alloy steel, it possesses much greater resistance to corrosion with either painted or unpainted surfaces. It has high fatigue and impact values, at normal and sub-temperatures, with the abrasion resistance of a medium high carbon steel . . . resulting in longer life of products.

N-A-X HIGH-TENSILE has outstanding cold-forming properties, and its response to welding, by any method, is excellent. Due to its inherently fine grain and higher hardness, it can be ground and polished to a high degree of lustre at lower cost than possible with mild carbon steel.

Your product can be made lighter in weight . . . to last longer . . . and in some cases, be manufactured more economically, when made of N-A-X HIGH-TENSILE steel.

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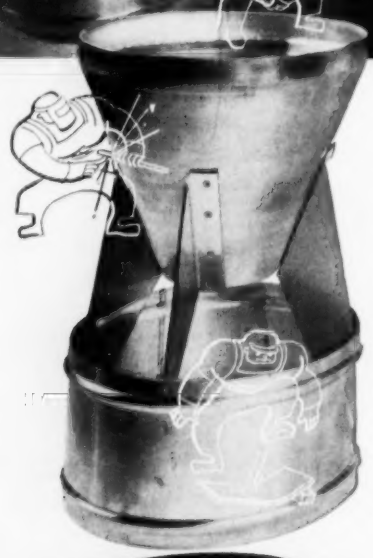
BRANDTS "BIG THREE"



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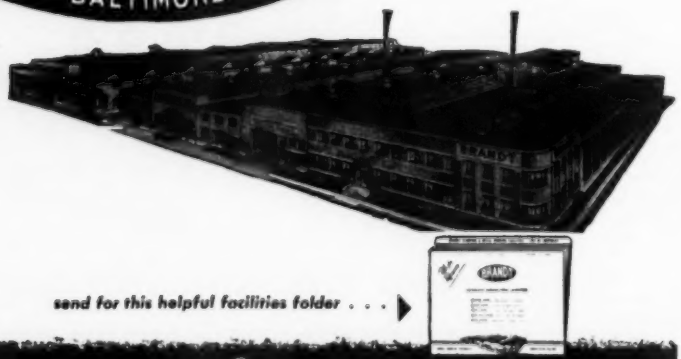

send for this helpful facilities folder . . .

CHARLES T. BRANDT, INC. Baltimore 30, Md.

Steelmaking Practices Compared With British

(Continued from p. 140)

access by roadway to certain parts of the works should be provided.

The development of heavy steel production in works attaining the standards of size suggested presents many problems, but can be aided by simplification of the range of products, specialization by works and lowered costs of delivery. Simultaneously with plans for development of the British iron and steel industry, plans should be made for the redeployment of labor and for the building of houses.

CHAPTER 10

The success of the maintenance department may be measured by the amount of downtime due to unplanned stoppages and the number of man-hours consumed. In both respects the American figures are good, and considerably better than British with regard to man-hours. The reasons for this are mainly as follows:

The layout, operation and capacity of the mills are such that planned stop days are arranged during the week and not concentrated into the weekend as in Britain. This permits a better workload on the maintenance department.

Lubrication is organized in a special department and mechanized wherever possible. Plant design is very robust and well above the operating capacity required.

CHAPTER 11

There are great variations both in America and in Britain in the degree of cost-consciousness and the extent to which costs are used. Managements of some companies in both countries could learn much from those of more advanced outlook. American costing techniques were not found to be any better or on a more uniform basis than those in Britain.

Performance statistics and, so far as possible, costs, should be made available at all levels of management, and interest in them should be stimulated by frequent and regular discussions based on cost reports and statements.

Records of manning should be kept on a standard basis so that comparisons can be made between various periods and conditions. Such

(Continued on p. 144)

MORE TIME FOR STEELMAKING... LESS TIME ON REPAIRS

You can keep steel-mill machinery on the job longer by using HAYNES hard-facing alloys to protect wearing parts. With hard-faced parts, you will have less down time and fewer repairs—more time for steelmaking. Illustrated here are some typical savings that have been made.

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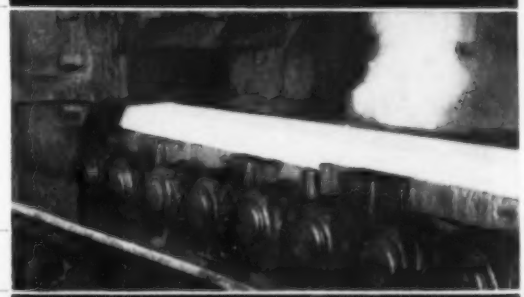
A yearly application of HAYNES STELLITE alloy No. 1 on this mud-gun screw for blast-furnace tap holes has eliminated monthly maintenance.

2

HAYNES STELLITE alloy No. 6 on the points of soaking-pit tongs has increased their life 19 times. Some hard-faced tongs have lasted as much as 50 times longer than unprotected ones.



3

The life of blooming mill shears has been increased 10 times by applying HASTELLOY alloy C on the cutting edge.

4

Entry guides for a bar-reduction mill used to wear out after handling 40 tons of steel. Guides hard-faced with HAYNES STELLITE alloy No. 6 last 4 to 5 times longer than unprotected ones.

5

Three years ago, some cone rollers in this bar-cooling bed were faced with HAYNES alloy No. 92. They are still in service.

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Please send me, without obligation, a copy of the booklet, "HAYNES Alloys—Hard-Facing Manual."

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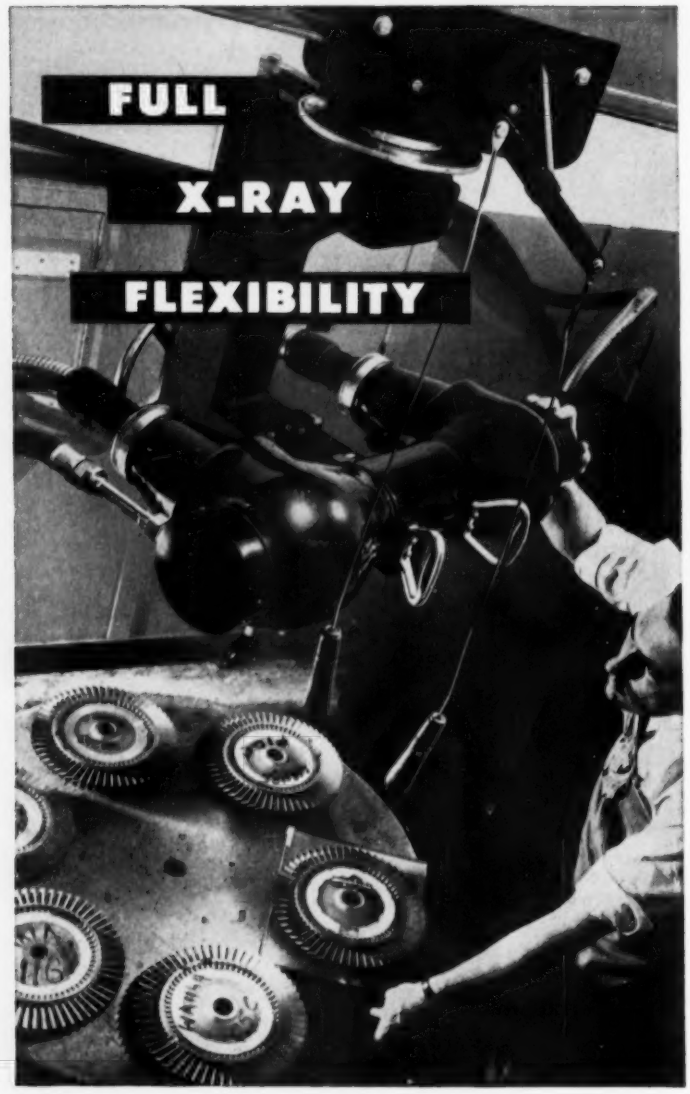

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YOU CAN BE SURE...IF IT'S

Westinghouse

Steelmaking Practices Compared With British

(Continued from p. 142)

records should be "married" to plant output rates (such as furnace productivities) to produce regular information on labor productivities or on labor consumption rates.

Statistics should not, however, be collected just by habit. At regular intervals – say yearly – the use to which all statistical data are put should be reviewed with the object of eliminating man-hours in the collection of unnecessary information, and to relieve management of an accumulation of paper work. Furthermore, a few man-hours spent in summarizing information and suggesting conclusions which may be drawn from it may save management many hours in assimilating it.

It would be a stimulus to the competitive spirit in the British steel industry if the exchange of plant performance statistics between works in which conditions of operation are quite reasonably comparable could be developed.

The statistics published annually by the British Iron and Steel Federation could be extended with advantage to give capacities of units of plant (calculated either on the basis used in this report or on some other agreed basis), design dimensions and characteristics, and the consumption rates of some of the more important resources.

It would also be extremely useful if an authoritative directory of the British Iron and Steel Industry could be published giving basic information about iron and steel works, their products, and the companies which operate them.

CHAPTER 12

The American steel marketing policy reflects the scale, the dynamic expansion and the higher degree of standardization in the steel-consuming industries. These have fostered optimism and risk-taking in the development of markets for the products of new types of large mills and for other new products.

Postwar developments in the British steel industry have made, or will make, most of these new products available in this country, and there should be similar possibilities of developing the market. An aggressive policy of marketing will, however, be necessary.

Productivity in the U. S. industry

(Continued on p. 162)

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BULLETIN BOARD

* the buyers guide for metals engineers

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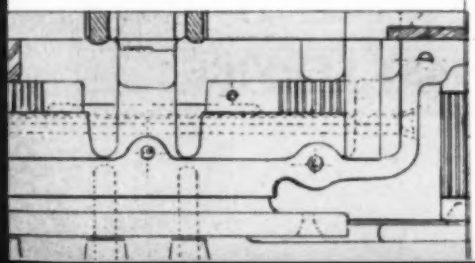

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Shatter-proof Park Cut Wire Shot is made of hardened clipped carbon steel wire. It will outperform and outlast breakable cast shot. That is why you can save up to 66% in cleaning and peening costs.

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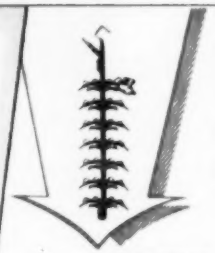

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NOT GRAY
NOT FADED
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BUT RICH, DARK, UNIFORM
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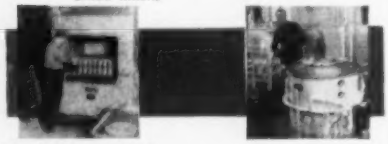

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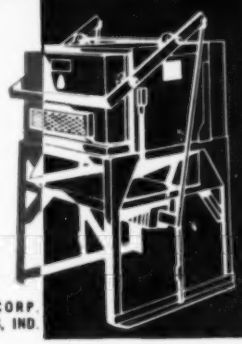

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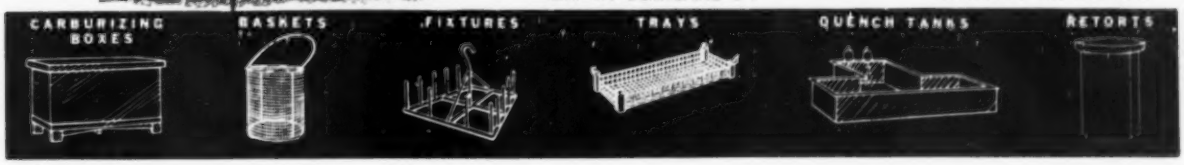

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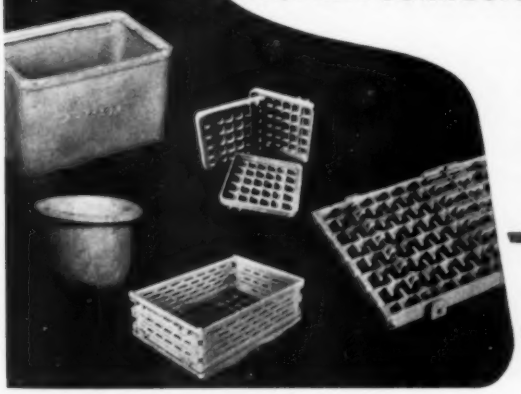

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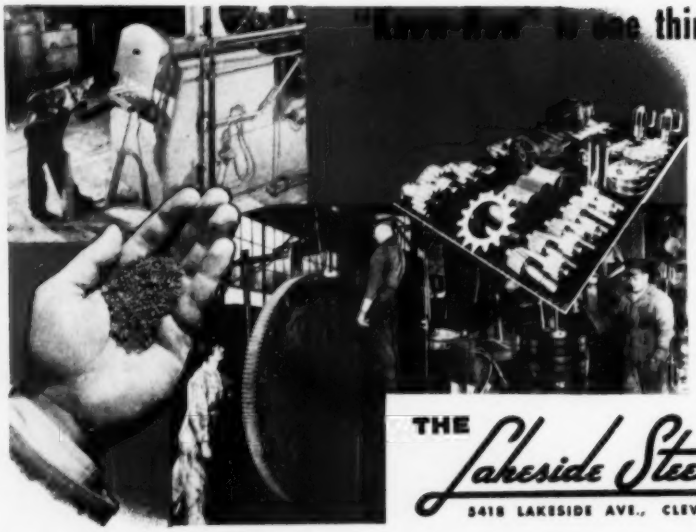

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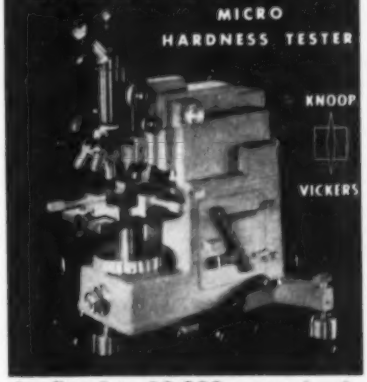

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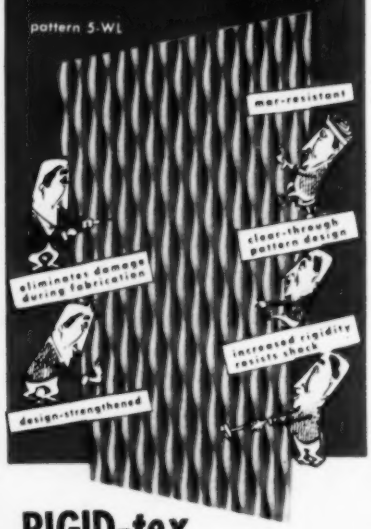

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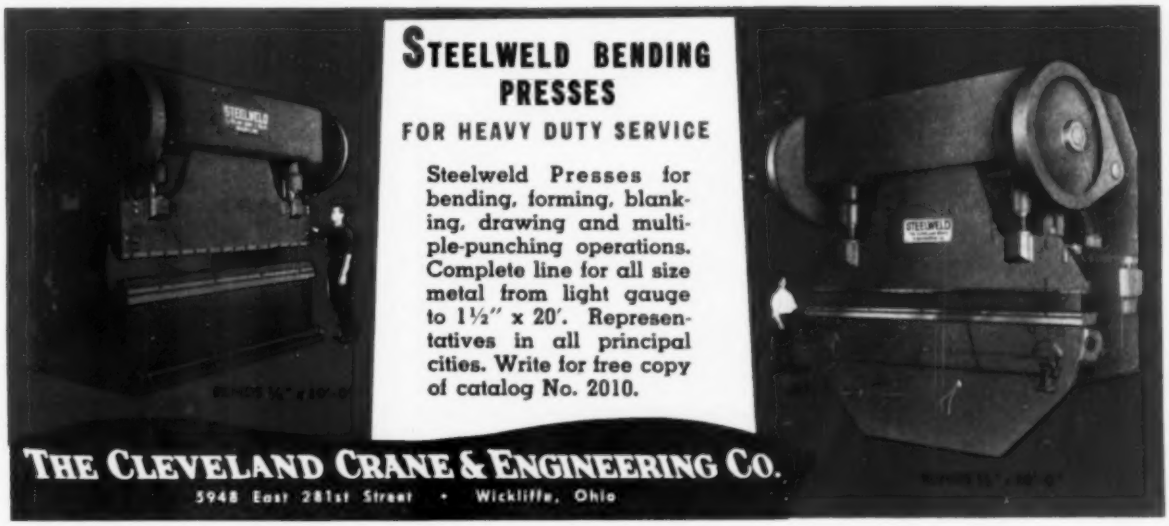
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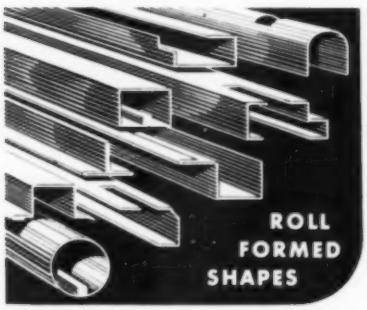

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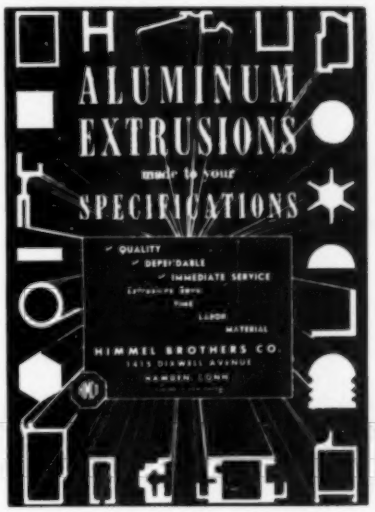

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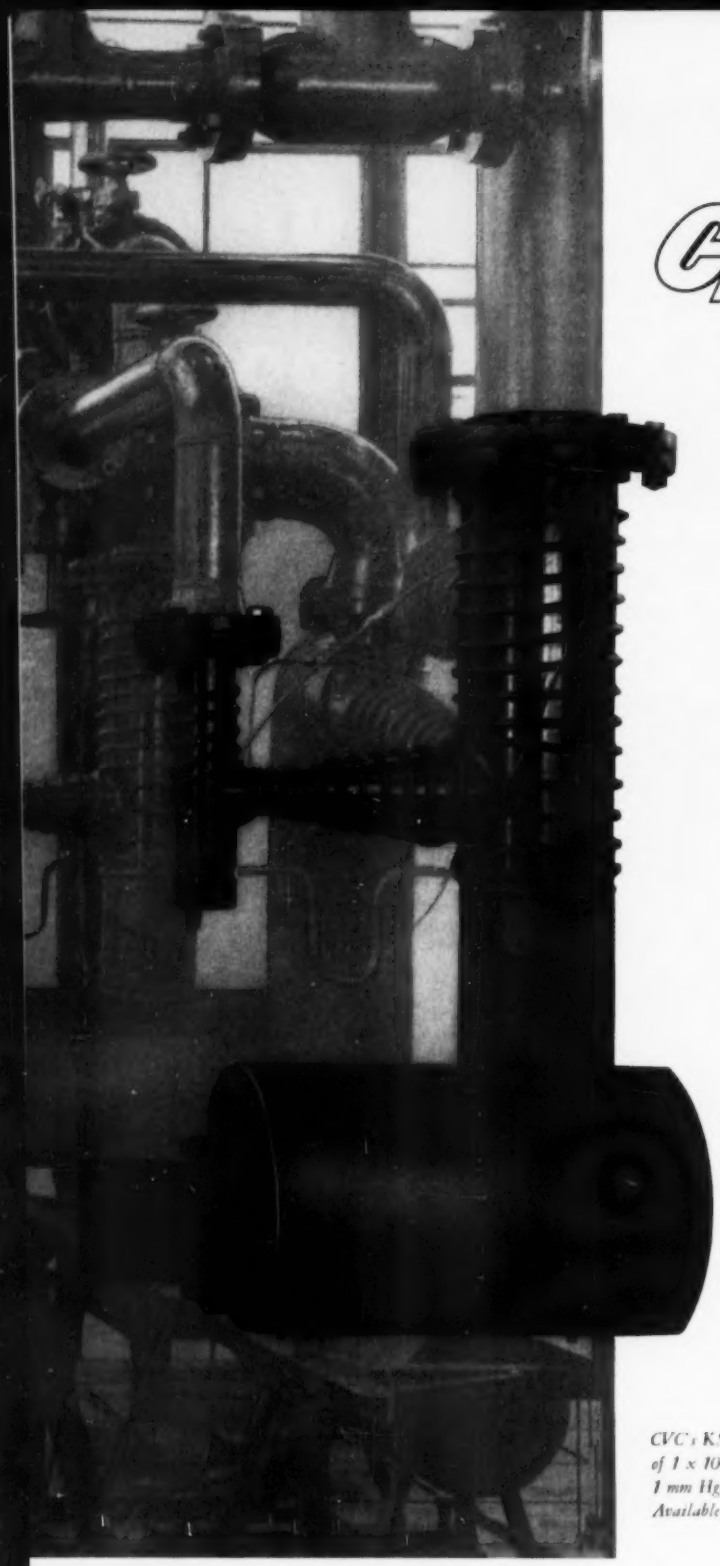

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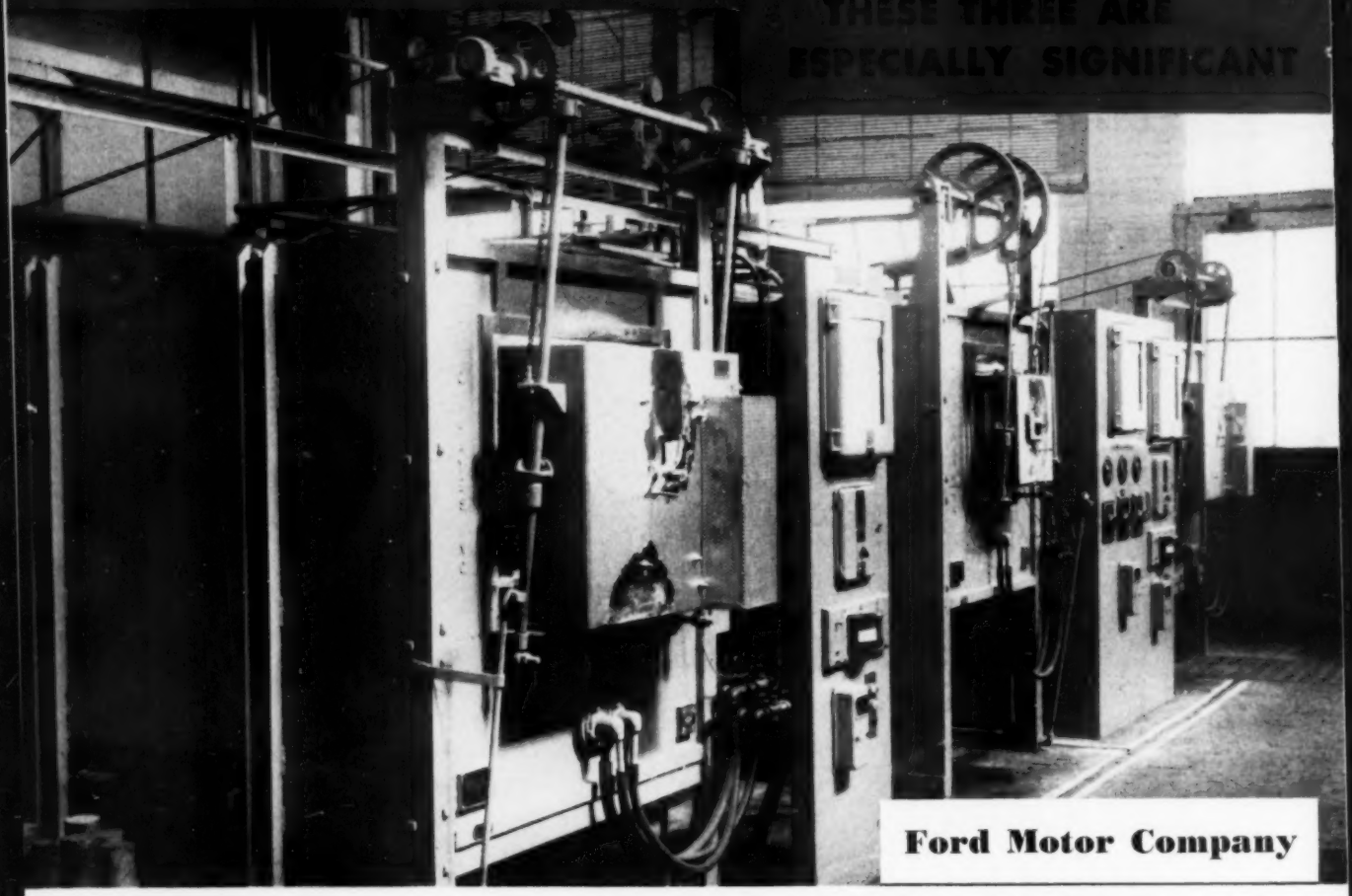

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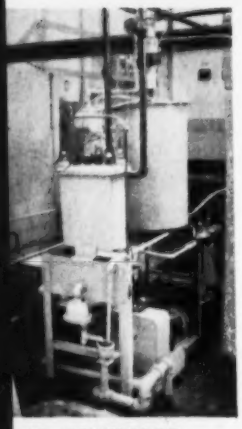

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Furnaces shown are HG71 and two LR90s, covering temperatures ranging up to 2400° F. to meet High Speed and Carbon tool steels' hardening and drawing requirements. Two IG Atmosphere Generators are located between the furnaces, with piping so arranged that either or both generators can serve any or all of the furnaces. Timeclock equipment automatically brings furnaces to temperature ready for use at start of shift.

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Cylinder liners cost a lot of money, and, of course, they take up space that could be used for generating extra horsepower.

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American Iron and Steelmaking Practices Compared With Those in Great Britain

(Continued from p. 144)

is also assisted by the active discouragement of small orders and of special qualities and sizes. This is achieved by charging high extras for small orders and by refusing orders for less than certain minimum quantities. A contributory factor is the high freight rates charged for small tonnages.

The system in the United States is derived from and favors the development of large and specialized production units and of warehouses in all parts of the country. The applicability of all these methods to the United Kingdom should be examined.

At the same time, the present trend toward decentralization of the U. S. industry shows that the benefits of producing large quantities in a concentrated area can be more than offset by the costs of distribution to some of the more remote markets.

This trend to decentralization is further encouraged by the fact that while freight rates per ton-mile on finished steel are very similar to those in the U. K., freight rates on coal and ore are noticeably lower, reflecting the special facilities developed for the transport of bulk materials over long distances. The possibility of utilizing such facilities in this country requires further consideration.

A lowering of the U. K. freight rates on finished steel would increase competition and aid the development of efficiency in the steel industry by increasing the possibilities of specialization.

CHAPTER 13

The high standard of engineering design in American steelworks is due mainly to the strong and active plant engineering industry, coupled with the progressive outlook of American steelworks engineers. Ample spare resources exist to build and operate pilot plants, even for processes which are somewhat speculative.

Research inside the American steel industry is on a relatively small scale, owing perhaps to the comparatively simple metallurgical problems in that country. Ferrous metallurgical research in the country as a whole is on an extensive scale, and receives considerable financial assistance from the Government and from the using industries.

British research effort continues to be strong and even to increase in strength, but development work suffers from many obstacles at the present time. Cooperative research in Britain has been found to be an efficient way of increasing the technical strength of the industry.

CHAPTER 14

The gross profits in 1950 of the American steel industry stood at nearly twice the rate of the British, and, despite a higher rate of taxation, higher dividends were paid and larger surpluses retained in the business. Despite adverse conditions, the British industry has reinvested accumulated surpluses of the same relative magnitude as the American.

American depreciation charges are somewhat more rapid than British and reflect the American attitude that the life of a plant is limited by obsolescence arising from technical development and improvements made by competitors rather than by the rate of wearing out.

Special tax allowances have, when operative, provided almost equal incentives to development in the American and British industries. The

(Continued on p. 164)

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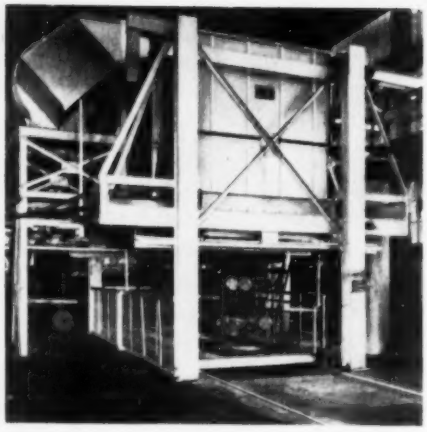

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Young Brothers Ovens are designed and built to meet the most exacting requirements of the metal-working industry. • Leading manufacturers in this field are finding that Young Brothers Ovens are vital in improving the quality of their products and increasing production. Various branches of the Armed Services, too, have approved the use of Young Brothers Ovens where heat treating applications are required. For over 50 years Young Brothers has been continually developing batch and conveyor ovens for new processes, materials and products. The proven dependability of these ovens for heat-treating requirements up to 950° F. is your assurance of finest results at lowest cost. • Experienced engineers are available for consultation without obligation. Write for Bulletin 14-T on heat-treating.

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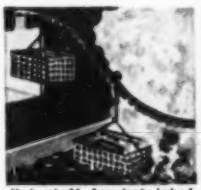
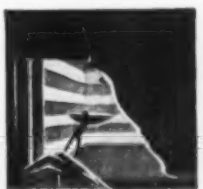
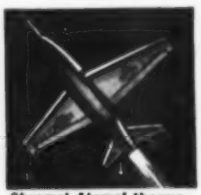
Yet that's exactly the kind of alloy that Hoskins is qualified to produce best. For, among the other quality-controlled alloys developed and manufactured by Hoskins are: Alloy 717—for facing engine valves; Alloy 785—for brazing belts; Alloy 502—for countless heat resistant mechanical applications. Then, too, there are the Chromel-Alumel thermocouple alloys . . . guaranteed to register true temperature-EMF values within specified close limits. And, of course, Hoskins CHROMEL . . . the *original* nickel-chromium resistance alloy used as heating elements and cold resistors in countless different products.



Hot stuff for hot jobs! Hoskins Alloy 502 is ideally suited to many mechanical-structural applications.



Heating elements made of Hoskins Chromel deliver full-rated power throughout their long and useful life.



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American Iron and Steelmaking Practices Compared With Those in Great Britain

(Continued from p. 162)

periods of their operation have, however, been significantly different.

The current rate of capital re-equipment of the British steel industry of £60 million (about $170 million) a year must be maintained and even increased if progress in overtaking arrears is to be made. Bold steps will be required if the country is to overcome the series of self-aggravating phenomena which stand in the way of finding production resources for capital re-equipment of basic industries, including the steel industry.

Any reduction in the cost of making steel requires the combined effort of the iron and steel industry and the industries most closely connected with it, namely the coal industry, the railways and the capital equipment industry. A higher proportion of Britain's national resources needs to be devoted to capital investment in these industries. E. C. WRIGHT

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Effect of Composition on Rupture Test Properties of Cr-Co-Ni-Iron Base Alloy*

THIS REPORT PRESENTS additional results obtained by the authors from their general investigation of the effect of chemical composition on the high temperature properties of certain of the so-called "superalloys". In this study 62 modifications of an alloy, known commercially as N-155, are considered, with rupture tests of up to 1000 hr. duration at 1500° F. being used to evaluate the variations in composition. The analyses of the base steel and the modifications considered are tabulated on p. 166.

As might be expected for a complex alloy of this type, the authors were not able to arrive at too definite conclusions. They did find, however, that none of the variations considered possessed a rupture strength at 1500° F. which was appreciably better than that of the base analysis. Thus, wide variations, at least in a single element at a time, can occur without impairing the strength. From this it would follow that on the basis of the 1500° F. rupture strength alone, the more critical alloying elements in this analysis (nickel, cobalt, columbium and molybdenum) might be reduced without adversely affecting the strength. Before such alterations are made, however, consideration has to be given to other characteristics, such as hot workability and structural stability.

Insofar as the effect of variations in the individual elements is concerned, it appears that *(a)* the optimum carbon content for maximum rupture strength at 1500° F. is 0.40%, *(b)* nitrogen and manganese had little effect over the range considered, *(c)* silicon decreased the strength, and *(d)* the optimum amount of chromium is 20%; of nickel, 10%; of cobalt, 10 to 20%; of molybdenum, 3%; of tungsten, 2%; and of columbium, 1%. However, when the composite effect of these elements is considered, they must be properly balanced so as to keep the structure completely austenitic. The presence of ferrite not only decreased the strength but promoted the formation of sigma phase.

(Continued on p. 166)

*Digest of "Influence of Chemical Composition on Rupture Test Properties at 1500° F. of Forged Chromium-Cobalt-Nickel-Iron Base Alloys", by J. W. Freeman, J. F. Ewing and A. E. White, Technical Note 2745, National Advisory Committee for Aeronautics, Washington, D. C.

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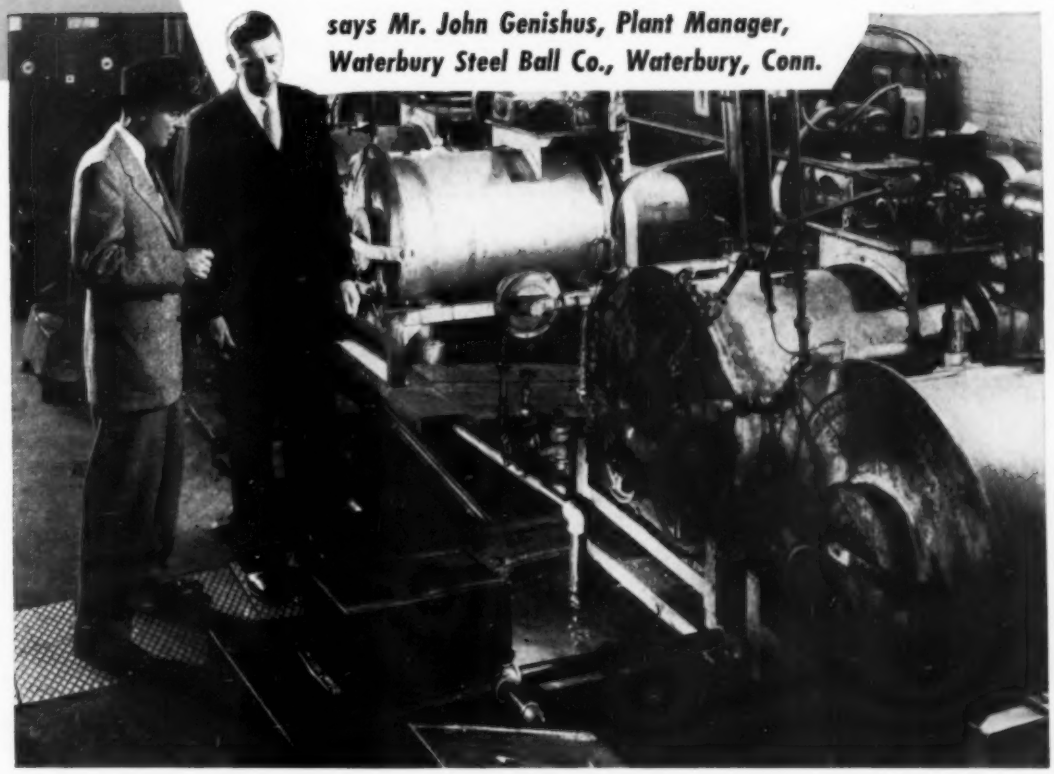

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Rupture Test Properties of Superalloys

(Continued from p. 164)

The authors found the combined effect of molybdenum, tungsten, and columbium to exert the greatest influence on the 1500° F. rupture strength. Their results show the combination of these elements present in the base analysis, namely 3% Mo, 2% W, 1% Cb, to be as effective as any. When the sum of these three elements exceeded 6 to 8%, the strength decreased. The elimination of columbium could be offset by the presence of 4% each of molybdenum and tungsten as far as the strength was concerned, but columbium was necessary to impart good hot ductility.

As yet the authors have not been able to obtain definite correlations between microstructure and high temperature strength properties, or to explain the fundamental effects of the individual elements on high-temperature strength. Some relationship between carbon, molybdenum, tungsten and columbium seems to be a controlling factor, at least for the base analysis they considered, but the exact role of these elements, either singularly or in combination, is still open to speculation.

C. L. Clark

	Base Analysis	Variations in Percentage of Content
Carbon	0.15%	0.08, 0.40, 0.60
Nitrogen	0.12	0.004, 0.08, 0.18
Manganese	1.7	0, 0.30, 0.50, 1.0, 2.5
Silicon	0.5	1.2, 1.6
Chromium	20.0	10, 30
Nickel	20.0	0, 10, 30
Cobalt	20.0	0, 10, 32
Molybdenum	3.0	0, 1, 2, 5, 7
Tungsten	2.0	0, 1, 5, 7
Columbium	1.0	0, 2, 4, 6
Iron	Balance	Balance

All heats were melted in a 9-lb. induction furnace with calcium silicide being used as final deoxidizer. The heats were quenched in water from 2200° F., and then aged for 24 hr. at 1400° F.

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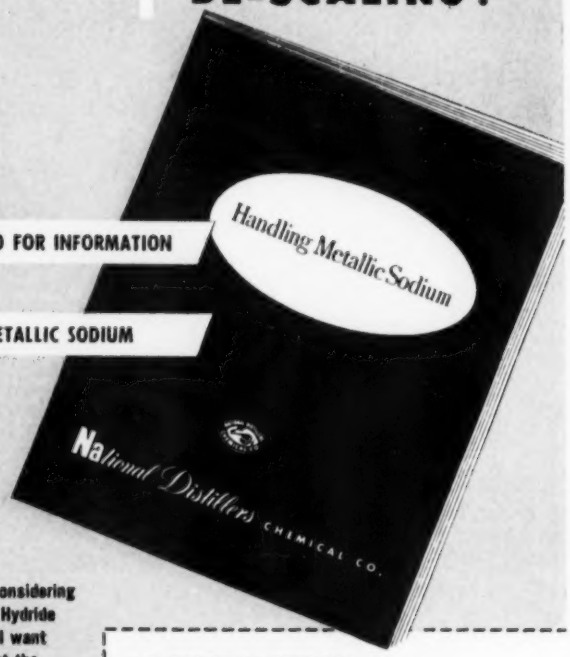

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Vacuum Brazing of Clad Steels*

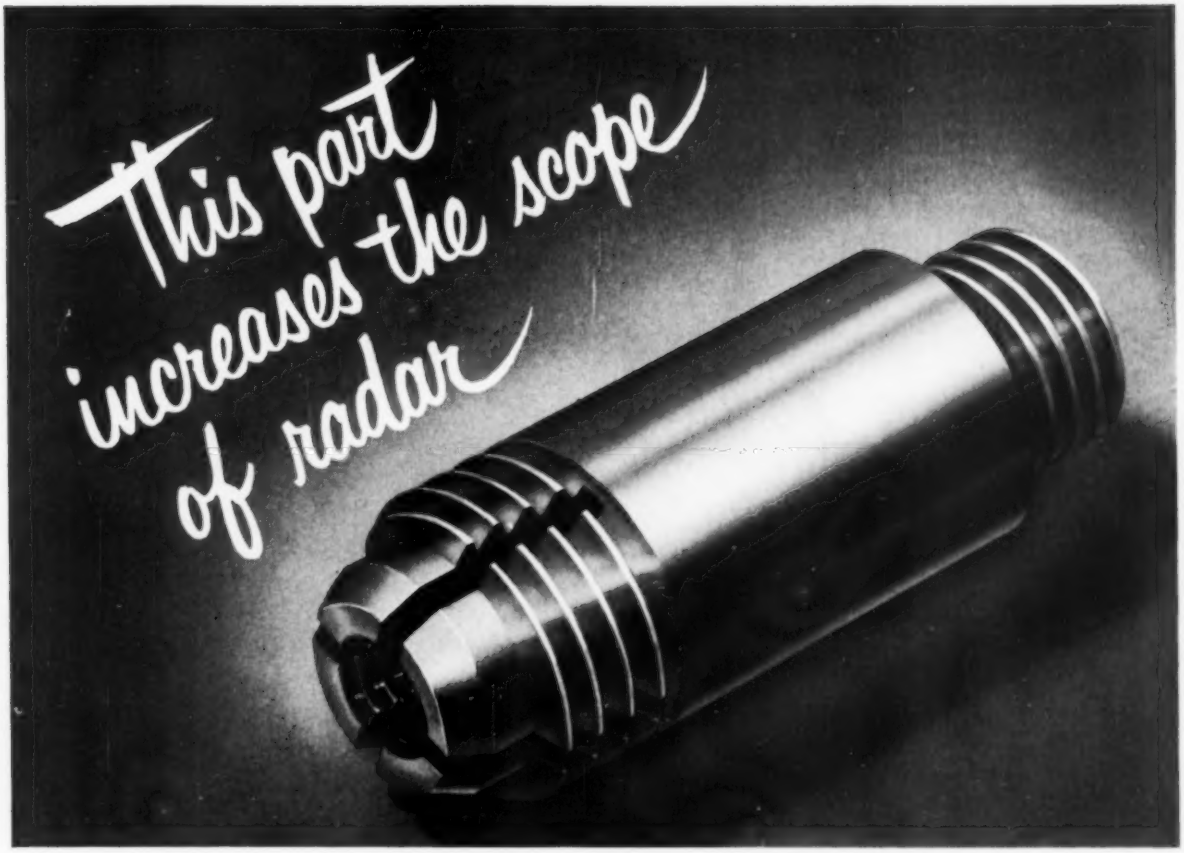
A system of vacuum brazing has been developed by the Chicago Bridge & Iron Co. in conjunction with the Southern Research Institute, both of Birmingham, Ala. By this method, brazed joints of high overall shear strength with continuous and uniform bonding can be readily obtained without the use of fluxes or special furnace atmospheres.

Of interest is the application of vacuum brazing to the manufacture of composite carbon steel - alloy clad plates. The several advantages over the conventional methods claimed for vacuum brazing are:

1. No heavy rolling equipment and accessories are needed.
2. Practically any size or shape of clad plates can be readily brazed with very little wastage of essential materials.
3. A clean surface free of contamination is always obtained.
4. The thickness of the alloy clad plates can be controlled closely.
5. When copper and copper alloy brazing are used in the vacuum process, a thin layer of brazing alloy allows a higher degree of alloying with the steel to give high shear strengths of bonding. Since the alloying in vacuum progresses rapidly, it

(Continued on p. 168)

*Digest of "High-Strength Vacuum Brazing of Clad Steels", by R. C. Bertossa, *Welding Research Supplement*, October 1952, p. 441s-447s.



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Berylco offers all these qualities to a superlative degree. For this particular part, which must be turned and threaded to close tolerance, machinability is important. In this respect beryllium copper offers special advantages through its age-hardening feature. This means that parts can be readily machined in a relatively soft condition and then hardened to give the desired combination of final properties.

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Vacuum Brazing of Clad Steels

(Continued from p. 166)

is not necessary to hold the plates for excessive periods of time at brazing temperatures, thus avoiding excessive grain growth, penetration and carbon migration from the base metal into the alloy layer (as in the brazing of stainless to carbon steel).

In the vacuum brazing of nickel and high-nickel alloys to carbon steels, special techniques are necessary because of the high solubility of copper brazing alloys in nickel and high nickel alloys. Close control must be maintained to regulate the diffusion of brazing material to give optimum soundness and continuity of bond for desired bonding strength. A micrograph of vacuum brazed monel layer bonded to carbon steel (46,500 psi. shear) shows that the penetration of the brazing alloy into both materials is limited, and that very little decarburization has occurred in the steel at the bonding interface.

The author has found that when various major types of stainless steels are vacuum brazed to carbon steels, there is a tendency for carbides which break down at the interface of steel and the copper brazing alloy to be removed to some extent with evolved gases by the vacuum in the system, thus aiding in minimizing carbon migration into the stainless layer. The vacuum also serves to remove oxidizing gases – such as CO_2, which form to a small extent in the interface – rapidly enough to prevent reoxidation of the stainless bonding surface during the heating-up period. Decarburization of the steel near the copper-steel interface is insignificant so far as over-all physical properties of the composite plate are concerned. The penetration of the copper alloy into the adjacent steels can be controlled to a degree where its effect on the physical properties is negligible. A micrograph is given to show the very slight decarburization of the steel and limited alloying of the copper alloy with the steels.

A number of brazing alloys can be used successfully in vacuum brazing. These include copper, brasses, bronzes, silver and other proprietary alloys. The successful application of silver alloy braze is particularly interesting, in that an excellent and continuous bond with good ductility and high shear strength (in excess of 50,000 psi.) can be obtained in the nickel and high-nickel alloy claddings without the use of the highly corrosive fluoride flux which is commonly employed in the conventional methods.

Extensive physical testings of the various types of composite clad plates have been carried out. Tensile tests have shown that the A.S.T.M. standards of 55,000 psi. tensile strength for A-285, Grade C, or A-201 and 65,000 to 70,000 psi. tensile strength for A-212 can be met successfully. A macrograph of a tensile fracture shows that the specimen necks down at the area of fracture, and that it does not split away at the bonding interface.

To test the ductility of the clad plates and brazing layer, 180° bending of the specimens flat upon themselves with the clad alloy either in tension or in compression has been carried out. Macrographs are presented to show results of such severe tests on Types 405 and 410 stainless steels, and nickel alloy clad plates. Examination of the tested specimens shows that no separation, cracking or other defects have occurred in the bond area. No defect exists in the clad layer in tension, but a small shallow crack is found to extend inwardly from the surface of the clad layer in compression. Such a crack, however, is also found in similar test

(Continued on p. 170)

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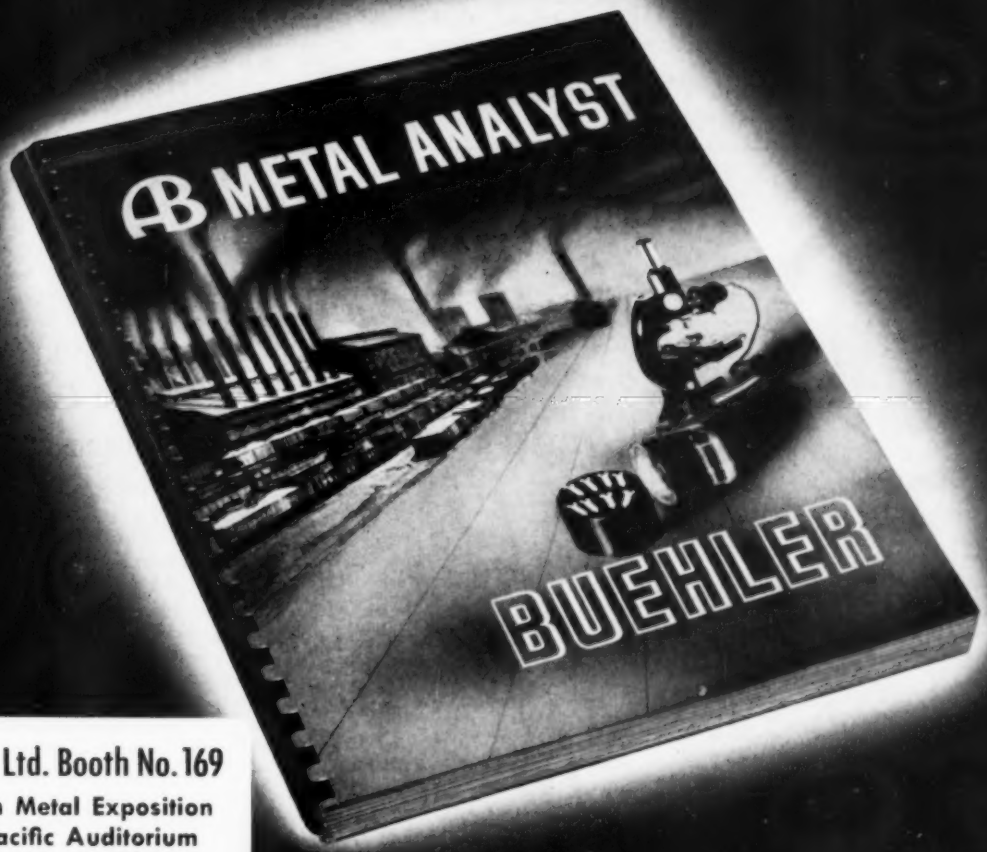

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Vacuum Brazing of Clad Steels

(Continued from p. 168)

specimens obtained by conventional brazing methods.

To determine the formability of the vacuum-brazed plates, a Type 405 stainless and low-carbon steel composite plate has been first dished cold and then flanged partly hot and partly cold. The bond has remained tightly adherent during such severe reverse bending and stretching.

Testings of the shear strength of the composite plates have been carried out. As a result, data are now available on shear strengths of well over 250 individual composite plates of various sizes and types. An average shear strength of 45,000 psi. has been obtained from these tests. Repeated heating and quenching of vacuum-brazed stainless and nickel alloy composite plates does not impair shear strength in the specimens.

Impact testings show that the transition temperature of the base metal (A-285, Grade C) after vacuum brazing remains in line with those of similar material in the normalized condition. Results of other tests, such as torsion test, high temperature shear test, corrosion tests, welding tests, etc., have also shown that the vacuum-brazed plates could pass successfully all of these.

Thus, vacuum brazing of stainless, nickel and high-nickel alloys to carbon steel shows promise of opening a new field in high-strength continuous brazing over relatively large areas of dissimilar metals.

No detail of the vacuum brazing process is given by the author, nor is the equipment described in any manner. Nevertheless, the reviewer is left with the impression that the process can be closely controlled to produce consistently good results.

W. L. Chu

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Soft soldering of aluminum and its alloys is complicated by the tough refractory oxide which forms immediately on the surface of these metals and prevents bonding of the tinning metal to the base material. This oxide resists the action of noncorrosive fluxes, although it can be removed by mechanical means such as wire brushing or scraping (methods at best tedious and not entirely effective), particularly on thin wire, foil and small pieces. Use of corrosive agents, such as hydrofluoric acid, is possible except that it may damage the base metal or cause after-corrosion in soldered joints.

Application of ultrasonic vibration for fluxless soldering, originating in Germany about 1936, offers a way to overcome the troubles experienced with other methods. This technique was discovered when the problem arose of tinning fine-gage aluminum wire for use in electrical measuring instruments. It was found that if molten solder was vibrated at a high mechanical frequency – around 18 kc. per sec. – the wire became tinned within a few seconds if placed in the solder near the vibration source.

Explanation suggested was that the tinning action was an indirect effect of the vibrations, a result of cavitation erosion of the oxide skin under conditions where no fresh oxide could form. Several practical

(Continued on p. 172)

*Digest of "Ultrasonic Soldering", by E. A. Neppiras, *Metal Industry*, Vol. 81, Aug. 8, 1952, p. 103-106.

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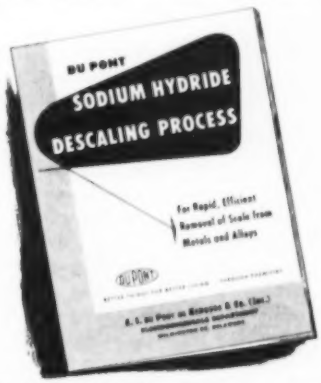

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Ultrasonic Cavitation "Tins" Aluminum Alloys

(Continued from p. 170)

devices incorporating the method were developed, but the method did not become known generally until some years after the war.

The action of cavitation occurs whenever a pressure wave of sufficiently high intensity is set up in any common gaseous liquid, including molten metals. If the amplitude of the pressure wave becomes greater than the static external pressure, normally one atmosphere, the many small bubbles present in suspension in the liquid are forced into violent radial motion. They expand rapidly as the liquid pressure becomes negative and collapse again during the positive cycle. The rapidly moving liquid in the vicinity of the bubbles exerts enormous local pressures, capable of causing severe damage to any solid surface on which the bubbles happen to be occluded.

If an ultrasonic vibrator, or transducer, is made to operate at high power in a liquid in contact with a metal surface, this type of "erosion" may start both at the transducer face and on the metal. This means that care must be taken to choose a resistant material for the transducer or to couple the vibrations from it to the liquid through another more resistant metal.

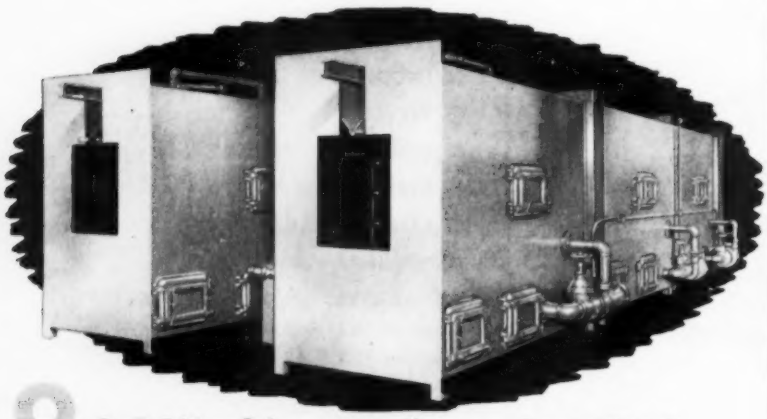
The process is feasible without damaging the base metal only if the film is less resistant to erosive action than the metal, which is the case in respect to aluminum alloys at soldering temperatures in the range of 350 to 660° F. In practical application, the cloud of cavitation bubbles in front of the ultrasonic vibrator tends to scatter the ultrasonic beam, confining the active zone to the immediate vicinity of the vibrator. If a large area is to be tinned, it is necessary to move the vibrator over the entire surface, always with a molten solder bond, although it is not required actually to touch the surface. Measurements show that oxide erosion is extremely rapid. Under typical conditions, effective tinning can be obtained in less than 0.05 sec. after the surface has reached the required temperature.

From the start, magnetostrictors have been the preferred type of vibrators. They embody the principle possessed by ferromagnetic materials of changing physical dimensions when subjected to a changing magnetic field. A typical design comprises a laminated structure having a closed magnetic circuit and wound with a toroidal coil. This is made to carry a direct current for biasing purposes and an alternating drive current of suitable value at the correct frequency for resonant excitation of the stack. The transducer vibrates as a half-wave resonator with maximum movement at the two ends and with a node at the center. In practice the vibrators are kept just ultrasonic, at frequencies above the audible limit of 16 kc. per sec., but below 25 kc. per sec.

Ultrasonic tinning devices may be either of the portable type, similar to a hand soldering iron, or of the stationary type, with the vibrating face of the transducer brazed directly to a solder container. The latter is easily adapted to continuous production, such as continuous tinning of wire and strip metal.

Although principal applications thus far have been to aluminum and its alloys, ultrasonic equipment can

(Continued on p. 174)



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Ready to give you on-the-job service . . .

Ultrasonic Cavitation "Tins" Aluminum Alloys

(Continued from p. 172)

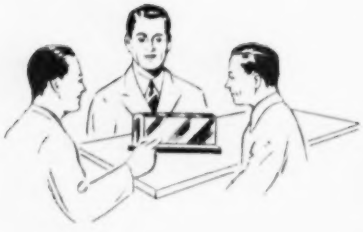
be used also to tin readily-soldered metals without any preliminary cleaning, even where surfaces are dirty or badly tarnished. All the light alloys can be handled, with the exception of those high in magnesium content. Certain other metals normally difficult to solder, such as stainless steel and chromium, can be tinned successfully if high ultrasonic intensities are applied. Beryllium and titanium are among the metals which have resisted attempts to tin by ultrasonic cavitation.

With metals other than aluminum, normal soldering methods depend upon capillary flow of the solder to obtain coverage, after a fluxing agent has removed oxide or prevented its formation. When tinning by ultrasonic equipment, fluxes are not only unnecessary but constitute a disadvantage in that the effect of cavitation would be to emulsify the fluxing material in the solder.

Applications of ultrasonic tinning cover a wide range, particularly as aluminum has come into wider use as a substitute for copper, and in the aircraft industry where weight saving is additionally important. In the radio industry, direct soldering of components to aluminum chassis and soldering of terminals to aluminum foil condensers and screening cans have been done effectively.

All soldered joints in aluminum and its alloys are susceptible to intercrystalline corrosion, but there is evidence that joints pretinned by the ultrasonic method show better resistance to corrosion, probably because of better area "keying". At present, tin-zinc or cadmium-tin alloys with compositions near the eutectic are generally recommended as the best soft solders for aluminum.

A. H. Allen



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Manganese From Openhearth Slags*

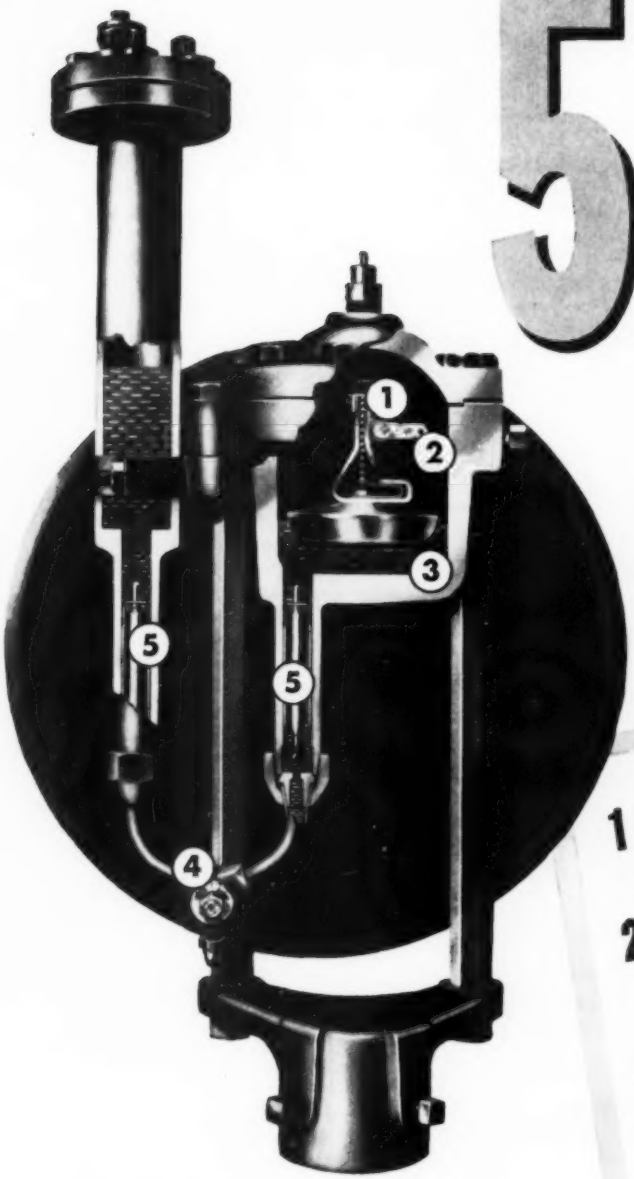
In *Metal Progress* for March 1951, E. C. Wright made the sensible proposal that the high-manganese slags taken from partly blown metal just before transferring it to openhearths in duplex steel plants be utilized for manufacture of silicomanganese or ferromanganese, thus substituting for an equivalent amount of imported ore. He also pointed out that if a certain proportion of low-manganese iron ores or openhearth slags be charged into blast furnaces, a pig iron containing 4% manganese could readily be obtained which would markedly speed up and facilitate duplex steel manufacture as well as produce a "green" slag containing 50% MnO, a much more valuable byproduct for recovery of the manganese. One of the advantages of this slag is that it is practically free of phosphorus.

Of course this proposal is applied to steelmaking methods responsible for a minor percentage of American tonnage; nevertheless the way is clear whereby some relief can be had from foreign dependence.

Since late in 1950 investigators at the Pittsburgh station of the U. S. Bureau of Mines, headed by R. C. Buehl and M. B. Royer and assisted by skilled plant personnel assigned by the American Iron and Steel Institute's subcommittee on manganese recovery processes (and partly financed by the Institute), have stud-

(Continued on p. 176)

*Digest of "Production of Spiegeleisen from Openhearth Slag in an Experimental Blast Furnace" and "Production of High-Manganese Slags by Selective Oxidation of Spiegeleisen", by Russell C. Buehl and Miles B. Royer, *Journal of Metals*, December 1952, p. 1289 and 1295.



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First in FLOW METERS

FACTORIES IN THE UNITED STATES, CANADA AND ENGLAND

Manganese From Openhearth Slags

(Continued from p. 174)

ied the much more general problem of recovering manganese from openhearth flush and top slags. A representative flush slag analyzed 11½% Mn, 21% Fe, 1.4% P, 29% SiO_2 + Al_2O_3 and 26% CaO + MgO. This was smelted in an experimental blast furnace with 24-in. diameter hearth, 29-in. bosh and 37-in. stack, the whole being 12 ft. 3 in. high. Blast was heated in a pair of pebble stoves, and production was about 3 tons per day. Flux was limestone and dolomite.

With blast temperature of 2050° F. and 4100 lb. of nut foundry coke per ton of metal, the spiegel produced contained 21.5% Mn, 1.3% Si and 3.9% P, 4.2% C, 0.10% S, balance Fe. In a series of runs on various slags and on a low-grade ore (11% Mn, 25% Fe) the manganese recovery ranged from 47 to 68%, which would be increased by 5 points if the flue dust were re-treated.

The second paper cited then discusses the difficult task of enriching this low-grade spiegel and eliminating its phosphorus. Advantage is taken of the well-known fact that silicon and manganese slag-out in the bessemer blow ahead of the carbon, phosphorus and iron. A basic-lined converter of barrel shape (end blown) with 500-lb. capacity was used, and blown with 275 cu.ft. of air per min. at 4 psi. gage. Molten charges were preheated to 2700° F.

Extensive German experience during World War II with this same scheme showed that the blow had to be stopped after only two thirds of the manganese in the spiegel was oxidized, else the slag would contain too much iron and phosphorus for use. Likewise the resulting slag was so viscous it could hardly be removed from the vessel. Experiments in Pittsburgh confirmed the fact that when the spiegel was blown so long that only 1% Mn remained with the unoxidized metal, the resulting slag had 11% iron and 1% phosphorus. On the other hand when the blow was stopped earlier, 5% Mn remained behind (apparent recovery 75%) and the resulting slag analyzed 58% Mn, 4.5% Fe, 0.25% P. Even then the slag was so viscous it held much entrapped metal (with its undesirable phosphorus). Thermochemical considerations indicate that if phosphorus is held to 0.15% max. the manganese-iron ratio will be above the 8:1 required for ferrograde ore.

Much better results were achieved by blowing the charge to about 1% residual Mn, pouring off the molten metal, adding a new charge of molten spiegel on top of the viscous slag retained in the converter. This slag became fluid very quickly, lost most of its entrapped metal globules, and could be poured out of the vessel. It contained less than 0.1% P and 3% Fe. 75 to 80% of the Mn in the spiegel charged reappeared in the synthetic manganese ore. Its principal drawback is too high SiO_2 — around 20%. Attempts to replace some of this with Al_2O_3 by charging appropriate amounts of aluminous clay during the blow gave a much more fluid slag but unfortunately much higher in phosphorus (1% or more). The authors believe that a larger converter would lose much less heat and the resulting slags would be much hotter and less viscous, even without alumina or other fluidizing agent. To test this idea, a 2000-lb. basic converter of conventional shape is being constructed.

E. E. T.

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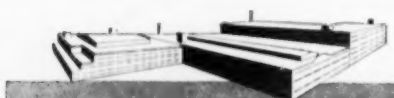

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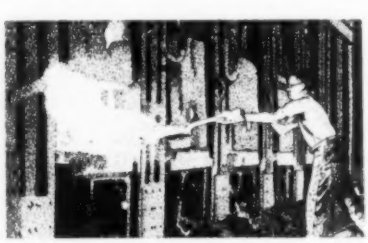

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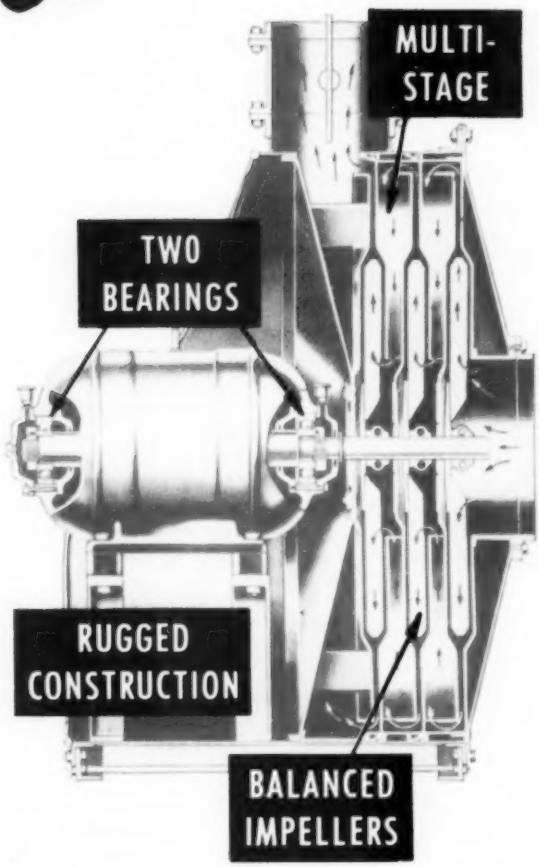

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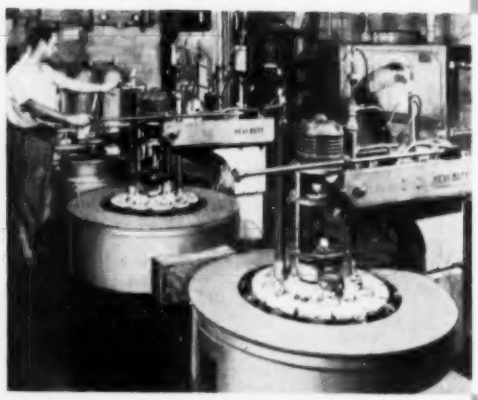

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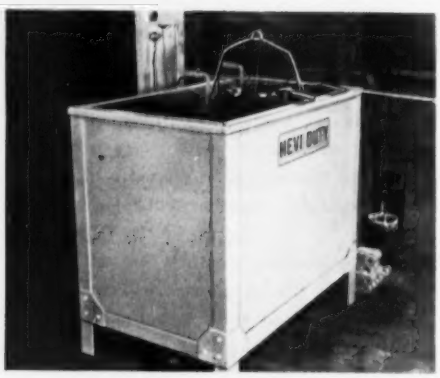

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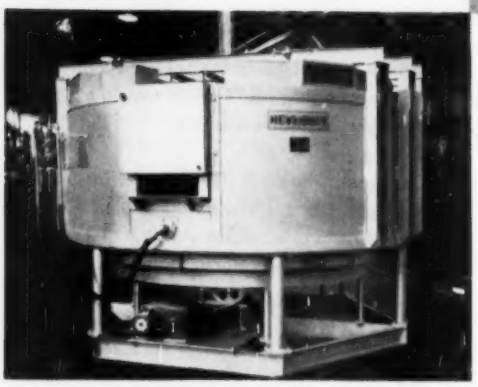

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Designed to operate at temperatures up to 2500° F. Many of these furnaces are heating jet engine parts prior to forging. A protective atmosphere prevents scale and the decarburization of high temperature alloys. Maximum capacity is 1500 pounds per hour. Bulletin 153.

At your service are experienced Hevi Duty Engineers able to recommend that exact furnace for your production system.

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Heat Treating Furnaces... Electric Exclusively

Dry Type Transformers *Constant Current Regulators*

Constant-Stress Tests for Creep in Metals*

A COMPREHENSIVE summary of the extensive work done by this author and his associates in the study of flow of metals is given in this Sixth Hatfield Memorial Lecture before the British Iron & Steel Institute.

The author states in his introduction that "the problem of the physicist is, starting with the simplest metals, to break down the creep into its component factors and to discover how they are governed by temperature, crystal form, grain size, the process of recrystallization, the distribution of external stress and local stress, and other circumstances."

Many years ago (1910) the author recognized the difficulties of studying creep phenomena under conditions of constant load; through the years he and his associates have devised numerous items for testing metals under constant stress. In a creep test at constant load, both the stress in the specimen and the rate of flow are increasing steadily, since the specimen is gradually reducing in area as the test proceeds. Under constant stress conditions the rate of flow is constant over a wide range of temperature and time, provided no structural changes occur in the test piece. Typical curves are shown which exhibit the great difference in creep for the two conditions of loading. The result of many constant stress tests on a variety of pure metals at several different temperatures was that the creep of all the metals, "measured as the extension of a normal polycrystalline wire under constant stress", could be expressed by one simple equation:

$$l = l_0 (1 - \beta t^{1/3}) \varepsilon^{kt}$$

where l equals length, t time, and β and k are constants. The β factor represents the initial or transient creep which diminishes rapidly with time, whereas the k factor expresses a flow of constant rate per unit of time and represents the permanent creep. This simple equation emphasizes that the testing of metals under constant stress leads to an accurate mathematical analysis of creep phenomena. It is surprising that, in

*Digest of "The Flow of Metals", by E. N. da C. Andrade, *Journal* of the Iron & Steel Institute, Vol. 171, July 1952, p. 217-228.

spite of this fundamental concept, most all of the reported high-temperature creep tests in the literature have been based on tests using constant load and not constant stress.

Extended series of tests of wires of the pure metals – lead, tin, copper, iron, cadmium and solid mercury – in temperature ranges between −180 and 500° C. (−290 and 930° F.) showed that the flow of these metals always obeyed the equation; the relative importance of the l_o, β and k varies widely with temperature and depends upon the closeness of the testing temperature to the melting point of the metal. An approximation ratio of the test temperature to the melting temperature on the absolute scale (T/Tm) yields a measure of the comparative flow characteristics of any two metals. Thus the ratio for lead at −180° C. (−290° F.) is 0.16 and copper at 15° C. (60° F.) is 0.21, and similar creep rate curves for these two metals are obtained at these two respective temperatures.

The transient flow factor β is a function of both temperature and stress. The relation is expressed by the equation:

$$Y = \int_0^x x^2 E^{-x^2} dx$$

This expression yields a sigmoid (S-shaped) type of curve; when β is plotted against stress a family of sigmoid curves is obtained at several temperatures. The author attributes the transient creep (β) to slip on glide planes within these crystals and, in a short time, this factor becomes insignificant.

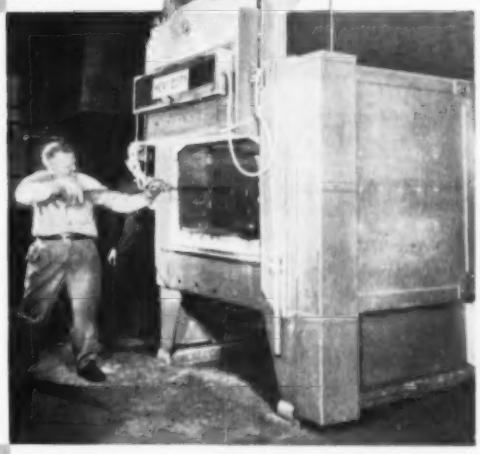
The permanent creep factor k yields a linear relation when log k is plotted against stress, indicating that k increases very rapidly with stress; several such plots of different flow curves for various metals show very close agreement on this point. Prestraining of tests (10%) eliminates the β factor and the creep curves exhibit only the constant k type of flow. The permanent creep is therefore concluded to be a grain boundary effect, due to relative adjustment of grains as a unit to each other.

Additional flow tests on tubular specimens, wherein the stress was pure shear, yielded interesting and surprising results, quite different from those of the tensile creep tests. In this type of test the shear strain

(Continued on p. 180)

HEAT TREATING FURNACES for INDUSTRY

HEVI DUTY



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Hardening piston rings at 1850° F. is one exacting use of this furnace. Hevi Duty design and construction assures uniform and fast heating with low maintenance costs in electric furnaces for many applications.

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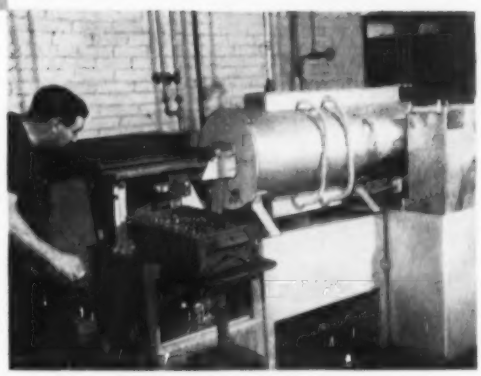
Salt bath hardening, tempering, and cyaniding without scale are major applications of the Hevi Duty Electric Pot Furnace. A case of .004 to .005 is obtained in 15 to 20 minutes on parts immersed in cyanide salt at 1550° F.

HEVI DUTY SHAKER HEARTH FURNACE

This modern production tool will either carburize, nitride, dry cyanide, or bright harden up to 150 pounds of work per hour. The work passes through the furnace and drops directly into the oil quench. Results are clean, uniformly treated parts with minimum distortion. Bulletin HD-850.



Hevi Duty Electric Company designs, and builds many types of electric heat treating furnaces and gas generators. Call on us to help solve your heat treating problems.

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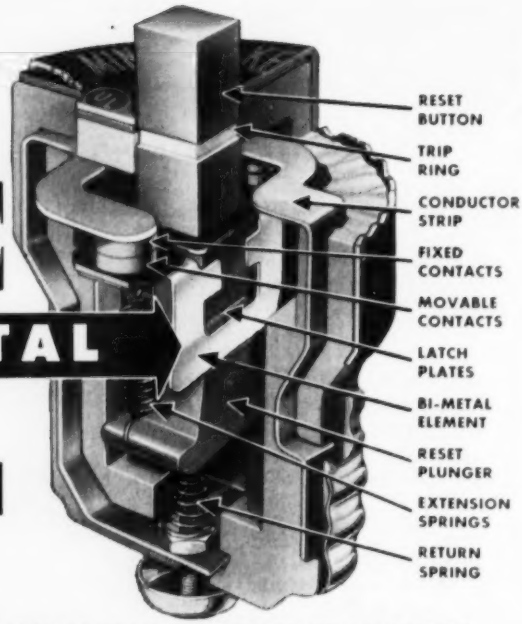


CHACE BIMETAL puts perpetual life in MECHANICAL PRODUCTS' MINI-BREAKER®

Product of Mechanical Products, Inc. Jackson, Mich.

The Mini-Breaker, manufactured by Mechanical Products, Inc., is a plug type circuit protector that provides positive, permanent protection against overloads and short circuits in electrical appliances and the wiring of residential or commercial buildings. Mini-Breakers are installed in Edison base fuse sockets and are built in 15, 20, and 30 ampere ratings. The trouble-free actuating element is largely dependent upon Chace Thermostatic Bimetal.

Under normal line conditions, electric current passes through the Conductor Strip and the Chace Thermostatic Bimetal actuating element, which carries a pair of movable contacts. On a direct "short" or a sustained overload, the excessive heat generated causes the element to bend away from the latch plates on both sides of the center reset plunger. A preloaded return spring then forces the plunger outward while twin extension springs pull the element and the movable contacts back . . . away from the fixed contacts . . . thus breaking the circuit. The circuit is restored by pressing in the reset button.

Chace Thermostatic Bimetal is manufactured in 29 types, in strips, coils, random long lengths and welded or brazed sub-assemblies. We also provide specialized tooling necessary to fabricate bimetal elements to customer designs. Before proceeding with your next design, we invite you to consult our Application Engineers, recognized authorities on temperature responsive devices—or write today for your copy of our 32-page booklet "Successful Applications of Chace Thermostatic Bimetal," containing condensed engineering data.

W. M. CHACE CO.
Thermostatic Bimetal
1626 BEARD AVE., DETROIT 9, MICH.

Creep in Metals

(Continued from p. 179)

was found to have a linear relation with $t^{1/3}$. This was found to be true at several stresses and temperatures for both lead and cadmium. The absence of the permanent flow factor k in the torsion tests is remarkable and emphasizes that the flow of a plastic wire under axial tension is not as simple as has been supposed.

Recrystallization of the metals was observed in many tests and the influence of this change was found to be a function of temperature. Above certain temperatures the metals recrystallized instantaneously, while the rate of crystallization decreased rapidly at lower temperatures. These effects gave points of inflection on the time-flow curves; below certain temperatures for each metal no evidence of recrystallization was noted. The shear tests were very useful in determining the rate of crystallization.

E. C. Wright

Active Metals Used as Brazing Alloys*

This report describes a series of exploratory experiments in the brazing of metals and nonmetallic materials by the use of brazing alloys of active metals such as titanium, zirconium, columbium and tantalum in vacuum or controlled atmospheres without fluxes. The active metals were found to "wet" both metals and nonmetals equally well, producing bonds often stronger than those of the nonmetallic materials. Included in the experiments were diamonds, sapphires, carbides, ceramics, glass, quartz, stainless steels and chromium-iron alloys.

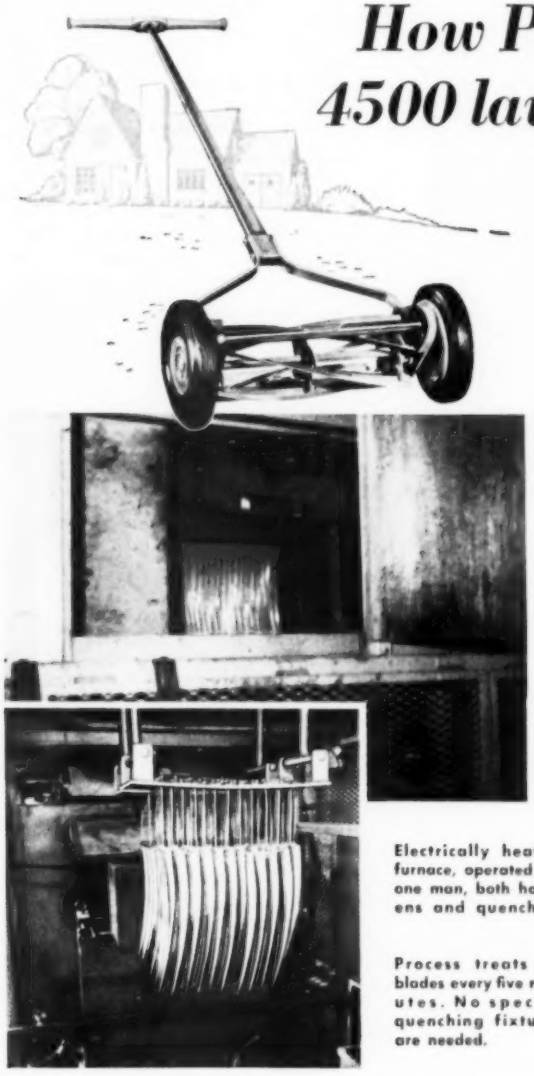
Brazed joints between metals and nonmetals have been made in the past by coating the nonmetal with titanium hydride. This paper shows that the hydrides of zirconium, columbium and tantalum can also be used, and that zirconium hydride possesses advantages over titanium hydride. It was additionally found that a 15% zirconium - 85% silver alloy could be used successfully for

(Continued on p. 182)

*Digest of "Metal to Nonmetallic Brazing", by C. S. Pearsall and P. K. Zingeser, Technical Report 104, Electronics Research Laboratory, Massachusetts Institute of Technology.

The Yard-Man Story:

How Park Salt Baths harden 4500 lawnmower blades a day!



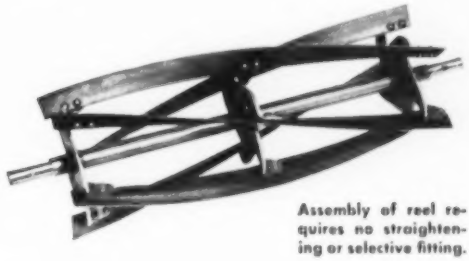
Electrically heated furnace, operated by one man, both hardens and quenches.

Process treats 55 blades every five minutes. No special quenching fixtures are needed.

There's a lifetime of rough treatment and rugged wear in store for most lawnmowers. That's why at Yard-Man lawnmower blades are precision heat treated in production quantities by austempering in Park salt baths. Park Nu-Sal and Park Thermo-Quench are used at Yard-Man to insure their blades the critical combination of hardness and toughness required. SAE 1065 blades, 55 per rack, enter and leave the furnace at 5 minute pushes. Park Nu-Sal neutral salt is the high heat at 1550° F. Quench is in Park's Thermo-Quench salt at 590° F.

Salt austempering eliminates scale, decarb and quenching cracks. Modern salt heat treating gives more and better production with less labor and floor space. One man handles the entire process, including loading and unloading. After salt bath treatment, reels are assembled *without the need of straightening or selective fitting.*

At Yard-Man, they've had over 2½ years now of trouble-free austempering with the Park salt baths . . . while maintaining their average production of 4500 lawnmower blades a day!



Assembly of reel requires no straightening or selective fitting.

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Nu-Sal Neutral Salt	Thermo-Quench Salt
M.P. 1230° F. W.R. 1300-1650° F.	M.P. 290° F. W.R. 325-1100° F.

Salt baths, the near perfect heating medium, offer tremendous advantages over conventional heat treating methods. As much as 80% of all heat treating *can be done better in salt!* Tools and dies, gears, bearing races, springs, cylinder sleeves, blades, automotive parts, agricultural implements, machine parts, ammunition and gun parts, just to name a few. Benefit your own product! You'll lower costs, increase quality by eliminating quench cracks, prevent scaling and decarb, increase toughness and ductility, and speed handling. You'll find, too, that Park austempering cuts labor costs while conserving valuable floor space!

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☐ Have Park representative call

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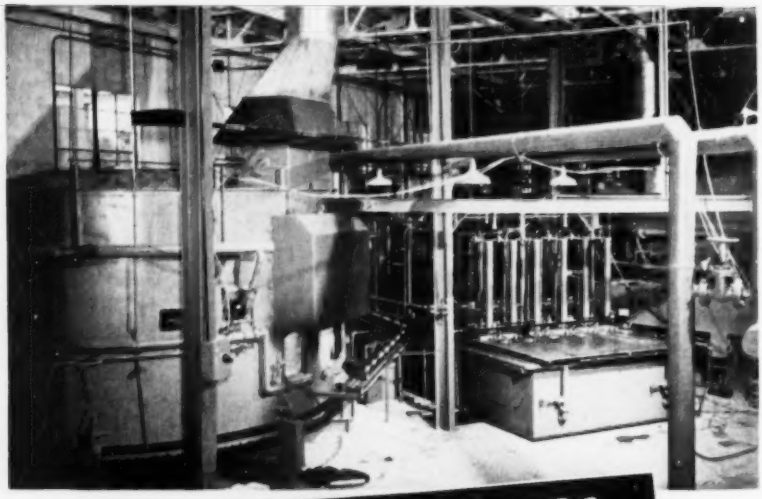

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The shells are hardened, quenched and drawn in a vertical position to ensure positive uniformity and accuracy. The result is better quality, faster production and lower cost.

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Active Metals Used as Brazing Alloys

(Continued from p. 180)

brazing metals to nonmetals directly. A number of special low-melting alloys such as lead-silver, aluminum-silver, indium-silver, and indium-gold were found to give good bond strengths with pyrex glass.

Considerable detail is devoted to the requirements for the atmosphere in which the brazing must be done. The hydrogen used must be very pure with the lowest possible oxygen and water vapor contents, and a simple test is described for the suitability of the hydrogen available. High-purity argon was used successfully with both titanium and zirconium hydrides. Conversely, pure nitrogen gave poor results with titanium, but excellent results with zirconium. Even commercial dry tank nitrogen could be used with zirconium, the appearance of some tarnish being insignificant in this case.

Emphasis is placed on the necessity for careful design when proposing metal-ceramic joints. Coefficients of expansion must be carefully matched over the temperature range involved. Since most ceramics are weak in tension, the joints should be designed to minimize tensile stresses induced during heating and cooling. It is additionally important to balance the heating because the metal absorbs heat at the greater rate and its higher temperature will tend to preferentially attract the brazing material. Two combinations which the authors found effective in preparing vacuum seals were 430 chromium-iron with Alsimag 243, and Kovar with ZI4. It is pointed out that where subsequent brazing operations may be required, the chromium-iron alloy may be obtained copper clad or may be nickel plated and the nickel built up in a hot bath to obtain a thickness of approximately 0.001 in.

The authors have no doubt that many practical applications may be made of the techniques they describe, although only a few have as yet been investigated by them. Examples are: Fabrication of radio-frequency windows for vacuum tubes, making of a cutter for ceramic tubing by brazing a diamond cube to the end of a steel rod, and the production of diamond

(Continued on p. 184)

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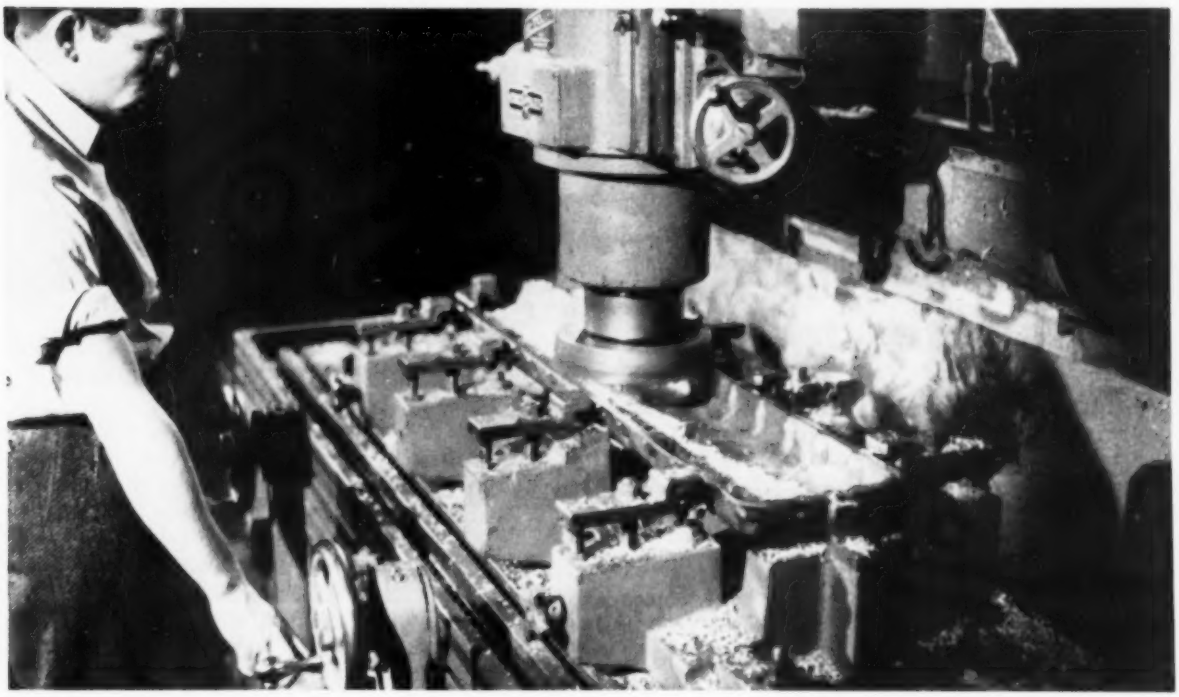
MAGNESIUM OFFERS YOU SUPERIOR MACHINABILITY

Increased tool life and lower machining costs are possible



Of all structural metals, magnesium is the easiest to machine. Heavier depths of cut and higher rates of feed than are used on other metals are possible when machining magnesium.

With increased machining speeds, magnesium helps you realize savings in production costs, particularly when extensive machining operations are required.

Magnesium cuts freely, too, assuring increased tool life. In fact, the life of high-speed steel cutting tools when machining wrought magnesium equals the life of carbide-tipped tools on other metals.

Excellent surface finish is obtainable when machining magnesium because there is no tendency for metal to tear or drag. Extremely accurate parts with dimensional tolerances of only a few ten thousandths of an inch can be made by standard machining operations.

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That's why it pays you to use this hydraulic-setting refractory for temperatures to 3000F

Blazecrete* materially reduces labor costs for refractory maintenance. This hydraulic-setting refractory saves time in building and repairing linings for high-temperature equipment.

For troweling, just mix Blazecrete with water as you'd mix ordinary concrete . . . then slap-trowel it in place. When gunned, it adheres readily with a minimum of rebound loss. Either way, Blazecrete goes on fast, without laborious ramming or tamping. And Blazecrete linings *last.*

Three types of hydraulic-setting Blazecrete are available. All harden on air curing, do not require prefiring. They are furnished as a dry mix—can be stored safely for use as needed.

3X BLAZECRETE—For temperatures through 3000F. Unusually effective for heavy patching, especially where brickwork is spalled or deeply eroded. Excellent for forge furnace linings, lime kilns, burner blocks, soaking pits, and industrial boilers.

STANDARD BLAZECRETE—For temperatures through 2400F. Makes repair work easier and less costly. Can be used by boiler manufacturers to replace fire clay tile in wall construction. Suitable for use in combination with 3X Blazecrete and L. W. Blazecrete.

L. W. BLAZECRETE—For temperatures through 2000F. An insulating refractory . . . light in weight, low in thermal conductivity. Adaptable and economical for many other applications.

Send for Brochure RC-28A on Blazecrete and its companion material, Firecrete*. . . the hydraulic-setting castable refractory for making special shapes and linings. Write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay St., Toronto 1, Ontario.

*Reg. U.S. Pat. Off.

Whether you gun it... *or slap-trowel it...*

Johns-Manville **BLAZECRETE**

BUILDS BETTER REFRACTORY LININGS

Active Metals Used as Brazing Alloys

(Continued from p. 182)

core drills by brazing diamond powder to steel tubing. Also, for high-temperature applications involving molybdenum, it was found that thin sheets could be brazed successfully in vacuum to beryllium oxide ceramic. Likewise tantalum sheet could be joined to aluminum oxide by use of an aluminum-zirconium brazing alloy.

Valuable and suggestive appendices to the report are the tables summarizing the results of joining numerous materials. These and the description of equipment and procedures which were used should serve as stimuli for both new researches and the broadening of application. L. E. ABBOTT

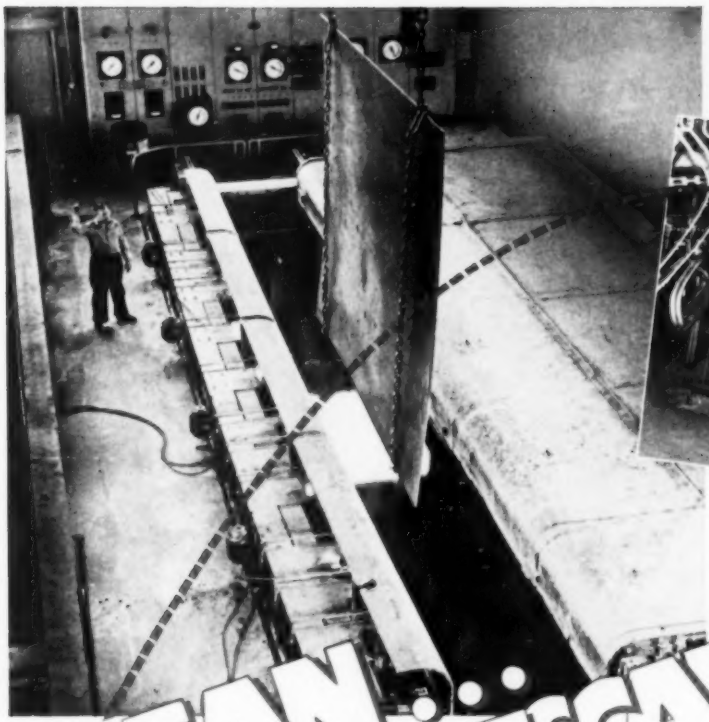
Maximum Temperature Applications for Type 316 Stainless*

THIS INVESTIGATION was made to determine the creep and rupture properties of Type 316 stainless sheet at 1200 to 1800° F. in annealed and as-welded conditions. In general, Type 316 stainless steel has been found to have superior high-temperature strength when compared to other austenitic chromium-nickel steels. Ease of fabrication, welding characteristics and freedom from embrittlement must also be considered for a particular application. Type 316 stainless steel is critically balanced with ferrite, austenite and sigma-forming tendency so that its embrittling characteristics must be determined. The sheet used in these tests was 0.062 in. thick, treated at 2000° F. for 30 min. and air cooled. This treatment gave a fully austenitic microstructure having a grain size of 2 to 4.

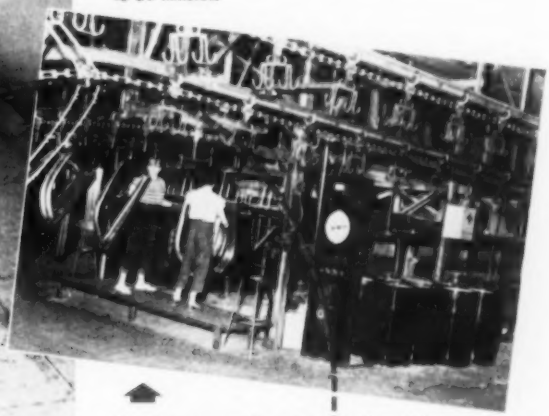
The creep and fracture properties of the material were determined on lever loading-type machines using standard sheet metal tension test specimens. The temperature was

(Continued on p. 186)

*Digest of "High-Temperature Testing of Type 316 Stainless Steel Sheet", by G. J. Guarnieri, Report No. AECU-1936, U. S. Atomic Energy Commission, Oak Ridge, Tenn.



Stainless, carbon, alloy and high-speed tool steels and non-ferrous alloys descaled in from 15 seconds to 20 minutes.



Drawing compounds and paint stripped from metal stampings in 50 seconds.

CLEAN... DESCALE... DESAND

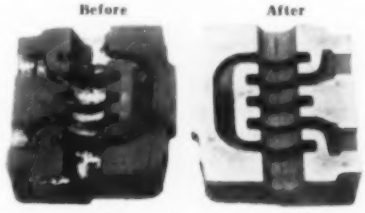
...faster, better at appreciably less cost

From removing metallic oxide scale from huge plates, coils or bars to desanding molds or cleaning residual materials from stampings, the Ajax Electric Salt Bath Furnace paves the way to appreciable savings in labor, floor space and time. What's more, the work is done far more efficiently than is possible with sand-blasting, acid pickling, electrolytic anodic cleaning or other methods.

The Ajax Salt Bath Furnace is adaptable to many metal and alloy types. Different metals and different metal shapes can be descaled simultaneously. The bath acts uniformly on all parts of the work including blind holes. The process reacts only on scale, sand or residual materials. The base metal is not affected and there is no hydrogen embrittlement. First cost of the equipment is low and so is upkeep. Pot and electrode life is measured in years and the bath can be regenerated indefinitely by the addition of low cost chemicals. Where desired, the entire process can be mechanized for highly efficient mass production.

Write today, giving details of your finishing problem. Let Ajax engineers prove these claims—at not the slightest obligation. Reprinted technical articles on cleaning, descaling and desanding are available on request.

Grease, drawing compounds, residual rubber, carbon black, plastics, paint and enamel removed in minutes with less labor.



Residual sand removed from these pump castings by 3-minute salt bath immersion at 700° F.

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The segment of a tank head illustrated is typical. Made of 1" thick, Type 302 stainless steel, the head blank measures 210" in diameter and weighs approximately 9000 pounds. So accurately was this segment produced that no "truing up" of the abrasive cut straight edge was required prior to welding two segments together.

It is this *unique ability* in handling *difficult* work that makes customers enthusiastic about the G. O. Carlson, Inc. services. For your next job in stainless steel plate . . . *let Carlson do it.* Your inquiry will receive prompt attention.

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Maximum Temperature Applications for Type 316

(Continued from p. 184)

maintained at ±3° F. of the nominal temperature over a 2-in. gage length. The strain measurements were made with extensometers working in conjunction with a cantilever SR-4 strain gage pickup device. The test specimens were sheared so that their longitudinal axis was parallel to the direction of rolling. The welded samples were prepared by butt welding with the Heliarc process without use of filler rod.

The creep was found for 1, 2 and 5% creep, and rupture at temperatures of 1200, 1400, 1500, 1600 and 1800° F. The time for testing was in the order of 1 to 1000 hr. The authors have presented the data in tabular form and show time-deformation creep curves and time-stress curves. Marked strain hardening occurred at 1200° F., so that stresses well above the yield strength were required to produce fracture in 1000 hr. As the temperature increased, the strain hardening characteristic decreased until at 1800° F. it was nonexistent. There was some loss in rupture strength of the welded material, the greatest loss occurring at 1800° F. The welded samples had about 10% lower strength at 1500° F. and about 35% lower strength at 1800° F. In all tests, the fractures occurred in the weld deposit. The fractures at 1200° F. were transgranular, at 1500° F. some intergranular failure was noted, and at 1800° F. the fractures were predominantly intergranular. Since failure occurred in the weld metal, it is possible that by proper selection of filler rod, higher strengths could be attained for the welded material.

A series of photomicrographs showed the microstructural changes resulting from exposure at 1200, 1400, 1500, 1600 and 1800° F. Sigma and some carbide were the predominant constituents formed from the parent austenite. Transformation was relatively sluggish at 1200° F. and only a small quantity of sigma was formed, primarily at the grain boundaries. As the temperature increased up to 1500° F., there was an increase in the formation of sigma. Above 1500° F., the amount of sigma decreased and was

(Continued on p. 188)

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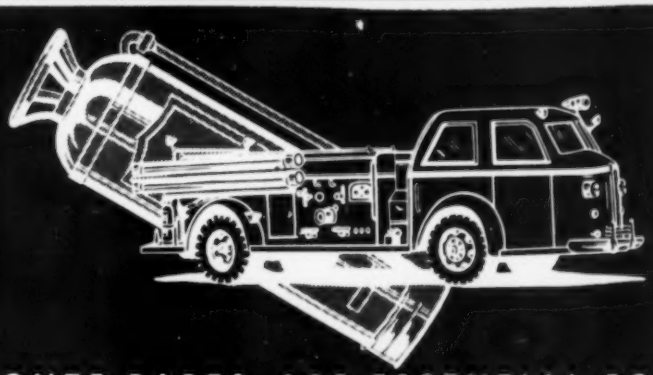

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Because liquid cyaniding of small parts for their famous heavy duty trucks meant high labor costs, International Harvester was looking for a more efficient method of case hardening. Their metallurgists decided that carbonitriding would provide the answer, and with the help and advice of the Armour Ammonia Technical Service Department they had the necessary equipment installed.

The change was even more successful than they had hoped. International's Fort Wayne plant reported lower labor costs, as expected, in carbonitriding thrust washers, shifting forks, brackets, miscellaneous pins, and similar small parts. They also found that carbonitriding's circulating gases assure a more uniform case on intricate parts. And carbon and nitrogen concentrations are more accurately controlled, resulting in fewer rejects. Finally, working conditions were much improved.

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Maximum Temperature Applications for Type 316

(Continued from p. 186)

nonexistent at 1800° F. An increase in hardness and a decrease in room-temperature ductility in bend tests was directly related with the formation of sigma. However, this loss in room-temperature ductility is not prohibitive. The stress-rupture results indicate that reasonable hot ductility can be expected for Type 316 stainless steel at the temperatures considered. The fracture-ductility decreases for long exposures at 1800° F. This decrease is due to marked intergranular deterioration as well as excessive general surface oxidation.

On the basis of this investigation, the authors state that in the design of structural components from Type 316 stainless, 1600° F. would be recommended as a conservative maximum temperature limit. Where short life expectancy would be sufficient, a peak of 1800° F. could be tolerated at stresses that fall below 1000 psi.

R. E. LOCHEN

SAP — Sintered Aluminum Powder for Higher Temperatures*

ALUMINUM has not been considered suitable for sintering because of the tenacious oxide film (about 0.01 micron thick) always present on its surface. If an aluminum powder is prepared, the oxide content of the powder will be a function of particle size and shape – that is, of surface area. Due to the plasticity of the individual aluminum particles, compacting is possible. Plastic deformation also breaks the oxide skin and this enhances sintering. However, complete sintering is possible only when pressure and moderately high temperature are applied simultaneously, and if this is followed by hot extrusion.

The procedure is to cold compact the aluminum powder under 30,000 to 70,000-psi. pressure, hot compact

(Continued on p. 190)

*Digest of "Sintered Aluminum With High Strength at Elevated Temperatures", by R. Irmann, *Metallurgia*, September 1952, p. 125-133.

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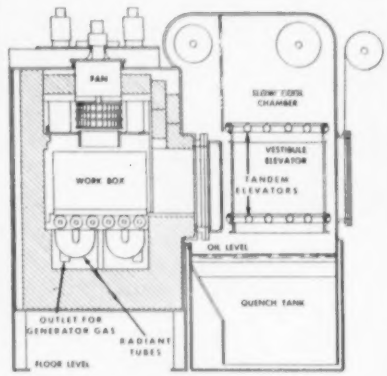

MODEL "J"

The Dow Model "J" is a small mechanized furnace for production carbonitriding, gas carburizing, clean hardening, carbon restoration and bright annealing. It is the ideal furnace for small heat treaters and manufacturers where flexibility is required. Size: 7'10" wide, 14'4" long—head room 15'. Production capacity: 250-350 lbs. per hour on light case work.

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Slow Cool Chamber permits cooling of a full furnace load in atmosphere and reloading without loss of time.

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SAP — Sintered Aluminum Powder

(Continued from p. 188)

at 930 to 1110° F. under 70,000-psi. pressure and finally to extrude the compact at 930 to 1110° F. under 70,000 to 140,000 psi. Pressing in a die can be substituted for the final extrusion. Products thus prepared have been designated SAP, which abbreviates *Sinter-Aluminium-Pulver.*†

Contrary to normal experience with powder metallurgy products, the properties of SAP (with 99.5% pure aluminum as the starting material) are similar at least to those of pure aluminum, and at most to heat treated wrought aluminum alloys, depending on the manner of powder preparation. Finer particle sizes result in higher strength properties (which is to say, strength increases with increasing oxide content). Ultimate tensile strength at room temperature of SAP containing about 12% of oxide is about 53,000 psi. Elongation for this composition is about 6%, which is comparatively lower at all strength levels than elongation for correspondingly strong wrought alloys.

An oxide content of 12% corresponds to a flake-like powder, with a considerable number of these flakes being 1 micron or less in thickness. Flake size and oxide content are not directly related, however. Heating of the powder results in increasing oxide content. Oxide content increases continuously as time is increased for the stamping or ball-milling manufacture of the powders, although particle size reaches a minimum after about 6 hr. of milling and thereafter increases as flakes form loose agglomerates.

Of greater interest than the room-temperature properties already mentioned, although they are quite remarkable for a powder product, is the stability of SAP on exposure to temperatures up to 900° F. This stability can be attributed to the fine grain structure of the product and the dispersion or network, as the case may be, of the oxide. Room-temperature properties are virtually unchanged after one month exposure at 900° F. Heat treated wrought aluminum alloys are, by comparison,

(Continued on p. 192)

†Swiss patents 250,118 and 259,878 and patents in other countries.

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Technical data sheet showing performance of Ferrovac 52100 now available. We can now ship from stock rods of 52100 in the following diameters — 15/16", $1\frac{1}{8}$", $\frac{5}{8}$". On order we will supply test samples or commercial quantities of vacuum-cast alloys to customer's specifications. Write for more information.

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If you'd like to know more about Magnaflux Corporation —its people and its methods—write for the booklet "Seeing Isn't Always Believing." Hundreds of businessmen and executives have found it interesting reading.

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SAP — Sintered Aluminum Powder

(Continued from p. 190)

almost completely softened after one day at 750° F.

Measurements of ultimate tensile strength at temperatures up to 900° F. (the testing being carried out after soaking at temperature for 30 days) indicate that SAP, starting out with a room-temperature strength of about 40,000 psi., still has a strength of about 14,000 psi. at 900° F. The corresponding strength for the best heat treated wrought alloys would be 60,000 psi. or more at room temperature and from 2000 to 3000 psi. at 900° F. Under the test conditions described, SAP and the best wrought alloys show equal strength at about 390° F.; SAP being increasingly more superior at higher temperatures.

The superiority of the high-temperature strength properties of SAP over wrought alloys is further demonstrated by measurements of 0.2% yield strength at 480° F. made after exposure at temperature for up to 540 days. The yield strength of SAP remained constant during this exposure and at the end of 540 days had a value 2½ times that of wrought alloys and 8 times that of pure aluminum similarly exposed.

Preliminary creep data indicate even greater superiority of SAP over wrought aluminum alloys at elevated temperature. Using the "Rohn method"—in which a test piece suspended in a furnace controls the heating current by its elongation—creep strength of SAP was found to be about three times that of heat treated and of annealed aluminum alloys containing 4% Cu, 1.5% Mg and 2% Ni.

The rotating bending fatigue strength of SAP at room temperature for round polished test pieces is about twice that of pure aluminum and comparable to heat treated wrought alloys, being about 15,000 psi. at 10^8 cycles. Notch sensitivity is 1.40. Repeated bending (pulsating stress, minimum zero) fatigue strength at 2×10^8 cycles over the temperature range of 70 to 660° F. revealed the fatigue strength of SAP at 660° F. to be about 16,000 psi. compared with about 3500 psi. for an aluminum alloy of 4% Cu, 1.5% Mg, 2% Ni. The duration of this fatigue test was 94 hr.

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Superheated steam scorches across them . . . centifugal force tries to tear them apart . . . and an out-of-balance turbine would be disastrous. That's the punishment these steam turbine blades have to take. And, that's the reason why they're forged and machined from Republic ENDURO Stainless Steel Bars.

ENDURO stubbornly resists corrosion . . . and rust. It maintains its great strength at high temperatures. It can be accurately and economically forged and machined.

Three different forms of ENDURO bars are used in turbine blade manufacture: hot rolled bars for forging larger blade sizes; cold finished bars for machining smaller sizes; and a cold finished special section, one of many such sections produced by Republic's Union Drawn Steel Division.

Have you an application in which you need increased strength? . . . increased resistance to corrosion? . . . plus economical machining? Then, investigate Republic ENDURO Stainless Steel . . . in hot rolled or cold finished bars, and in wire. Ask Republic for metallurgical assistance in applying them, too. Just write:

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A Research Engineer

(Continued from p. 96)

removed and fresh metal surfaces have been exposed; despite the hardness of the matrix, the graphite flakes in the plastically deformed surface are covered by deformed metal.

After the break-in process has been successfully completed, and the surface completely reworked and effectively transformed to one which is conformable to piston ring reciprocation, the surface is receptive to lubrication and capable of carrying on without scuffing or scoring. The complete wearing-in process has taken approximately two hours. The critical period has been passed and the cylinder is ready to go to work at full load in the hands of the user, without potential danger of a failure from scratching or scoring.

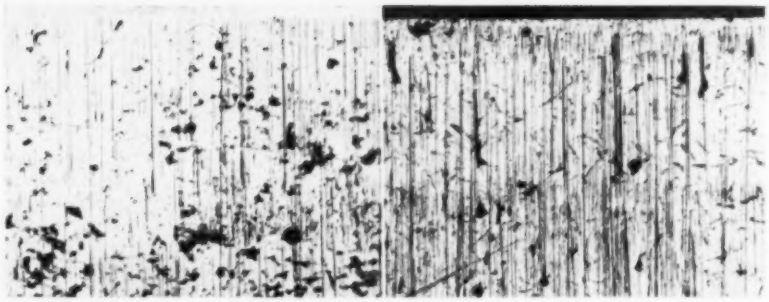


Fig. 6—Cylinder Liner Surface After Partial Break-In, Showing Vertical Abrasion Marks and Random Distribution of Graphite Pits. 200 ×

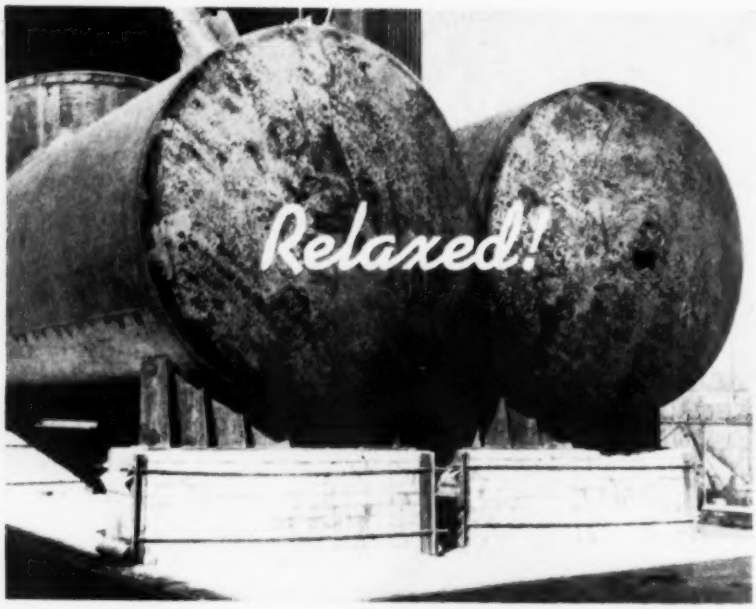
Fig. 7—Surface of Surfided Cylinder Liner After 100-Hr. Engine Operation. Graphite has been largely covered over by plastic-flow metal. 40 ×

Some trials have been made with chromium-plated cylinder surfaces, but the manufacturing processes have been so difficult as to warrant chromium-plated piston rings only when they operate against induction hardened cast iron. This combination has been sufficiently encouraging to warrant production.

Also in the last few years, interest has been manifested in ceramic cylinder liners. They are highly resistant to wear by dust, and to corrosion by high-sulphur fuels. In some wear tests under extreme conditions and high-sulphur fuel, induction hardened liners from regular production lost 0.010 in. in 500 hr. and ceramic liners only 0.0001 in. The top piston ring's temperature against the ceramic liner is about 10° higher.

Experimentation with ceramics has led to the opening of new vistas. Sealing of track roller bearings on tractors has always posed a difficult problem. These bearings operate in the maximum concentration of dust, deep mud, water, and at times at very low temperatures. Oil seals, designed to keep oil in and dirt and water out, have used steel for sealing surfaces. Regardless of heat treatment, hardness or surface treatment, all attempts were failures until porous materials such as ceramics, sintered coppers and sintered irons were used. The most significant factor was found to be porosity and not hardness as measured by Rockwell or other indentation methods. This leads to a generalization that a thorough-going knowledge of the properties which are significant for any particular application has to be determined.

(Continued on p. 196)



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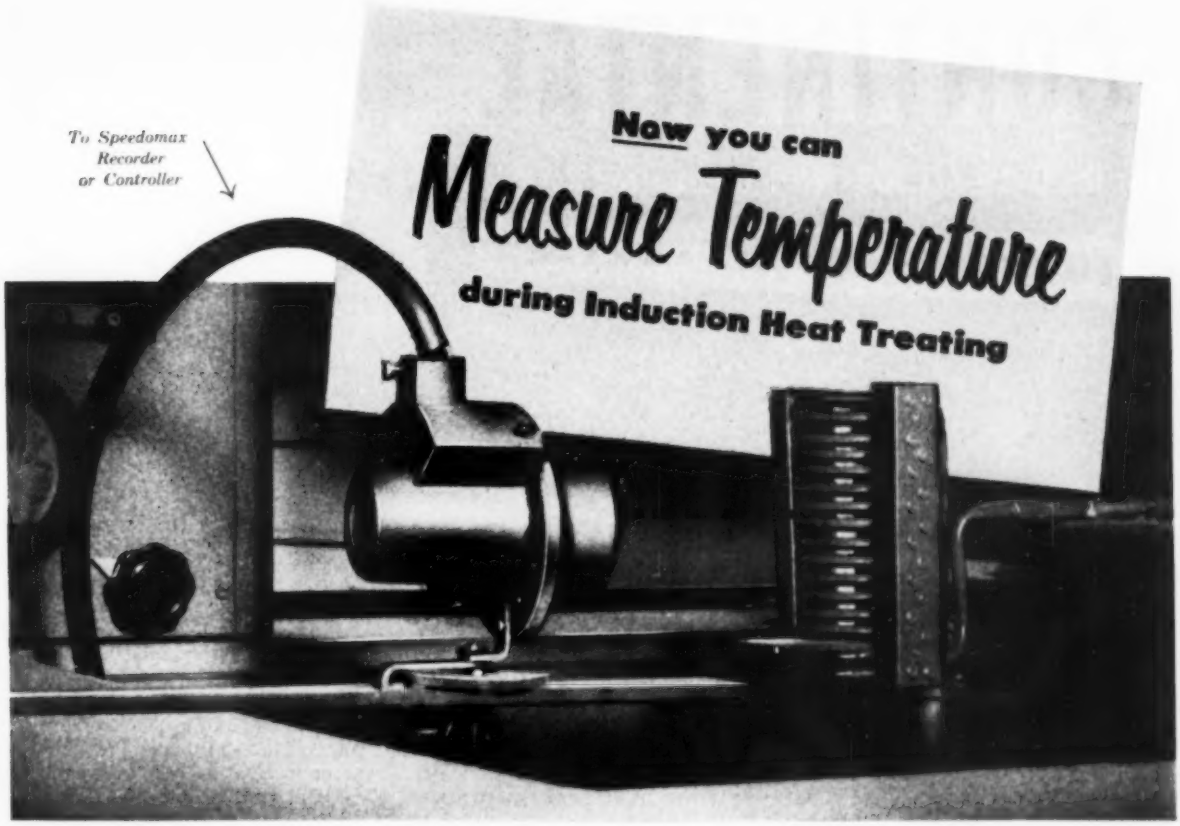

In this simplified set-up the Rayotube detector is sighting on steel bar stock between coils of the heating unit. A Speedomax controller connected to the Rayotube automatically regulates and records temperature.

This installation is at Lehigh University where the Dept. of Metallurgy uses a Lepel High Frequency Induction Furnace to investigate the influence of induction heating on the properties of various steels.

With this new Rayotube detector, it is possible for the first time to measure and control temperature of metal parts being heat treated by high frequency induction during their entire cycle.

Mounted only four inches from the induction heating coil, this newest member of the Rayotube family can focus on an opening as small as 0.1 inch between turns of the coil, and through this opening sight on the hot surface of the work. The Rayotube is so fast it reaches 99% of true temperature in 0.6 second . . . is always within 0.15 second of changes in work temperature.

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If you'd like more details about using Rayotube detectors on high frequency induction heating or similar applications, just write us at 4927 Stenton Avenue, Philadelphia 44, Pa.

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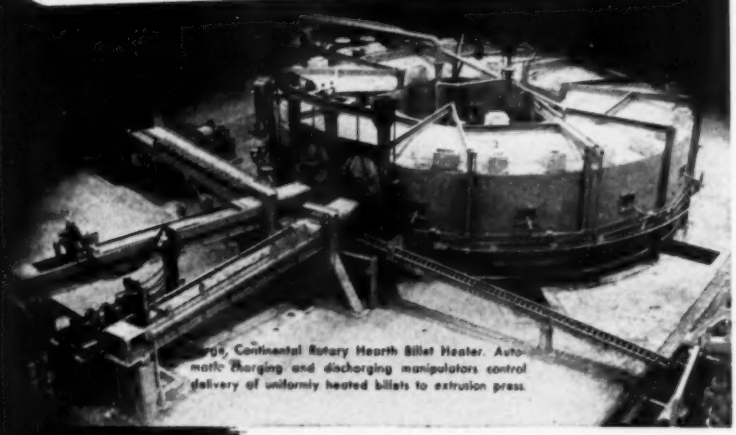

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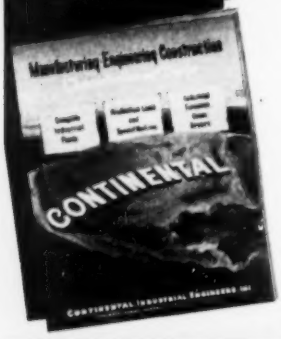

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MANUFACTURERS—ENGINEERS—CONTRACTORS FOR OVER A QUARTER OF A CENTURY

A Research Engineer

(Continued from p. 194)

This philosophy ultimately leads to full-scale proving-ground tests. According to Boegehold: "When the service performance of a machine part must be improved or when a substitute material is needed, mechanical tests on small specimens do not supply the information required for engineering decision. For this reason it has become a common procedure to test alternate materials in the form of fabricated components in the field."

Substitution of less costly material and the use of cheaper fabrication methods is illustrated in a crankcase member of a radial diesel engine which is made of cast iron, replacing an expensive steel forging. The stress analysis reveals the capacity of cast iron to take the imposed loads with the design characteristics developed by the designer and metallurgist.

High-output diesel engines need not weigh more than high-output gasoline engines of comparable displacement, even though we still are prone to bear the yoke of weight in diesel designs.

BEARINGS

In the trend toward higher speed diesel power units, and its attending reduction of size and weight, a definite bottleneck is found in main and connecting rod bearings. A material which has proven itself to be outstandingly successful under high sustained loads is aluminum-tin, steel backed. The bond between alloy and steel frequently developed a brittle interlayer, but bearings are now available which operate continuously in high-speed engines on crankpins at loads as high as 5000 psi. of projected area. Aluminum-tin has also proven very useful in the thrust bearings of turbo-blower superchargers, which are plagued by high heat transfer through the shaft and bearings; rotational speeds of 80,000 rpm. are not uncommon.

Aluminum-tin bearings are at present providing the designer and the metallurgist with a breathing spell. Undoubtedly the future will demand even higher bearing loads and bearing velocities. If the normal peak pressures of 1000 psi. in the cylinder can be raised, say, to 1800 psi., remarkable savings in fuel consumption will result. Further improvements in supercharged diesel engines with high cylinder pressures will require better bearings than are now available.

Yes, gentlemen, *less* than 5% ripple—and you know that means more uniform deposits. This exclusive new H-VW-M Rectifier also has dual input for either 220 or 440 volts. That's right, single knob control instead of several—but that single knob controls 22 points of on-load switching!

And that *oversize transformer* is another typical H-VW-M "extra"—operates continuously without exceeding a 25°C. temperature rise . . . *plenty of reserve capacity*. The acid and alkali-resistant coating on both the transformer and the selenium stacks is real assurance of dependable, long life. There's *increased plate area*, too—and easily replaceable Fiberglass dust-blocks to filter incoming air. And instead of an ordinary contactor, there's a standard starter to guarantee AC line-overload protection with no-voltage release.

These Rectifiers—*made* by H-VW-M—have a smooth, easy-to-clean, durable, grey, hammer-tone finish and are the most complete line in the industry. They're available with either self-contained or remote control, in a full range of sizes from 50 to 10,000 ampere units in all desired voltages. And by comparison, *they cost less per unit than any other rectifiers made!*

Superior, lower-cost rectifiers are just one of the many results of H-VW-M's constant progress in electroplating and polishing development for more than eighty years. It's a continuous policy, best summed up in H-VW-M Platemanship . . . your working guarantee of the best that industry has to offer—not only in rectifiers—but in every phase of plating and polishing.

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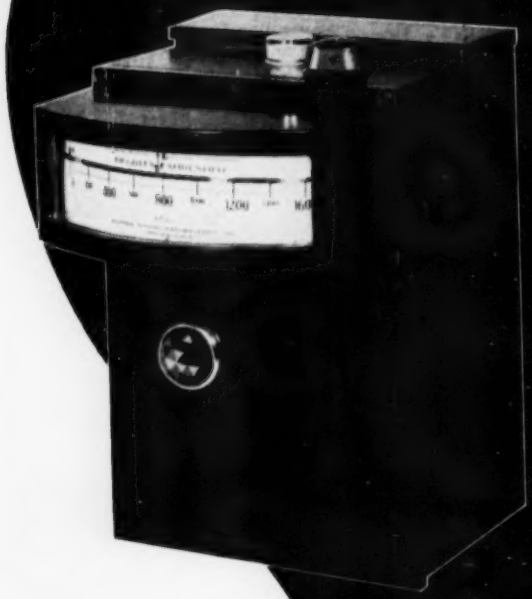

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Performance of Refractories in Basic Arc Furnaces*

DATA AS USUALLY presented on the performance of refractories in basic arc furnaces are not qualified as to exact conditions of service; consequently it is difficult to evaluate their performance. Frequently, minor changes in the use of refractories have been credited with surprisingly large effects on performance, whereas apparently major changes showed little if any effect.

Temperature and spalling have been most emphasized as the destructive factors contributing to poor performance. However, the factor which is perhaps the most important but which has received scant attention is that of furnace fumidity, or the effect of the fumes and atmosphere within the furnace during melting and finishing on the service life of refractories.

Experience with 17 basic arc furnaces ranging in size from 9 to 70 tons capacity indicated that the conditions of refractory service can be defined effectively by the melting practice required to produce the different analyses of electric furnace heats. Different melting practices produce different conditions of fumidity. This factor includes both the composition and amount of furnace dust or fumes and the composition and pressure of the furnace gases. The melting practices used at Republic Steel Corp.'s plant at Canton, Ohio, and against which refractory service is evaluated, are:

1. Oxygen-blown alloy using a low-alloy scrap charge, oxygen blow at time of meltdown and a carbide finishing slag.
2. High carbon alloy (greater than 0.70% carbon) using a carbide finishing slag.
3. Low carbon alloy (less than 0.70% carbon) using a carbide finishing slag.
4. Single slag practice using a single oxidizing slag.
5. Stainless steel practice using a charge of stainless scrap, oxygen blown on meltdown and lime-silica finishing slag.

Observations and analyses of furnace fumes and gases were made in evaluating the conditions of furnace

(Continued on p. 200)

*Digest of "The Effects of Melting Practice in Refractory Consumption, Furnace and Ladles", by M. P. Fedock, presented in Pittsburgh at the Tenth Annual (December 1952) Electric Furnace Steel Conference of the American Institute of Mining and Metallurgical Engineers.

INDUCTION HARDENING WRENCHES AT UTICA DROP FORGE CORP.

Wrench Life Increased Ten Times With G-E Induction Heaters

"By induction-hardening working surfaces with G-E induction heaters, we are now making wrenches and pliers that last ten times longer," says Maynard Gray, Foreman, Heat Treating Dept., Tool Division, Utica Drop Forge & Tool Corp., Utica, N. Y.

Utica has found they can heat treat *only* the areas to be extra hardened —leaving the internal structure of the tool unchanged and preserving the desirable toughness necessary to withstand stress and shock.

Lower labor costs and increased production are other benefits of G-E induction heating. At Utica one operator induction hardens 350 wrenches per hour or almost six per minute! In each case the tool is put on a special jig, heated, then immediately cooled by a jet of air.

Hardening is only one of many uses for G-E induction heaters. Other equally important applications are annealing, soft-soldering, brazing, and other jobs where it is necessary to localize the heating of parts. You'll find G.E.'s complete line of induction heaters can help you to accomplish your heating in the fastest, cleanest, and most economical way.

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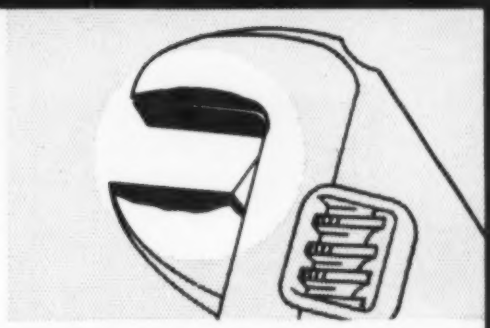
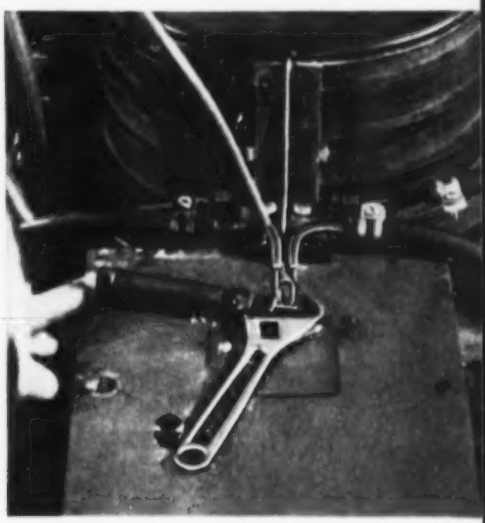
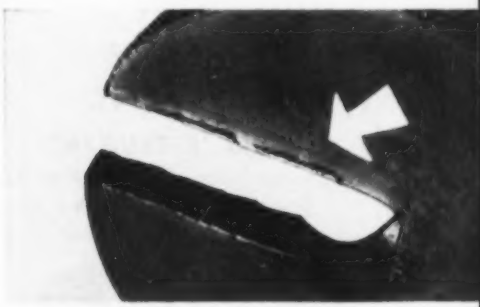


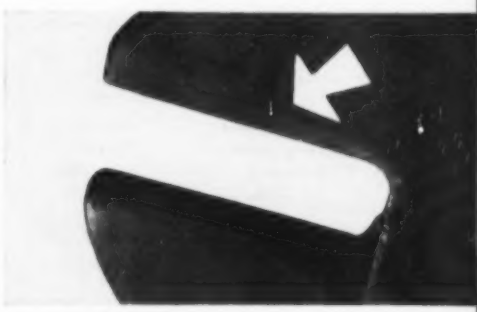
DARK AREAS SHOW where wrench-jaw surfaces are extra-hardened selectively by induction heat to resist burring and nicking.



SELECTIVE HEATING with G-E heaters is a fast process. With this special fixture, heating and cooling cycle takes only 10 seconds.



WITHOUT INDUCTION HARDENING wrench had tendency to wear or burr-over on the jaw surfaces after a given number of applications.



WITH INDUCTION HARDENING this same type wrench showed no burring or other wear when given 17 times the number of applications.

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Performance of Refractories in Basic Arc Furnaces

(Continued from p. 198)

fumidity developed by these melting practices. The pattern for the composition of fumes and gases is characteristic for each melting practice and this is due to differences in composition of the charged materials and composition of the furnace slags.

For example, in practice *1* the fumes at meltdown are essentially magnetic hematite (gamma Fe_2O_3). During the oxygen blow, much denser fumes of gamma Fe_2O_3 and magnetite (Fe_3O_4) are produced. After slag-off, when the carbide slag is formed, the fumes are chiefly lime (CaO) and periclase (MgO), with appreciable amounts of silica (SiO_2) and fluorspar (CaF_2). Before tap, the amounts of lime and periclase are about equal, the silica increases and the fluorspar decreases in the fume. A strongly reducing condition exists in the furnace atmosphere with the carbide slag, and up to 94% carbon monoxide has been observed in the furnace atmosphere at this time. During oxygen blowing, the higher oxides of iron (Fe_2O_3 and Fe_3O_4) are formed; these coat and penetrate the working surfaces of the refractories.

In oxygen blowing a stainless remelt heat *(5)* refractory chromite ($FeO + Cr_2O_3$) constitutes a major portion of the fumes and these likewise coat the working surface of the refractories. However, the strongly reducing atmosphere in practice *3* reduces the iron oxides formed and in the course of this reduction ferrous oxide (FeO) is formed which, together with the fumes of lime, periclase, silica and fluorspar, causes severe corrosive attack on the silica roof refractories. This is the most corrosive of the five melting practices enumerated. Practice *5*, on the other hand, is the least corrosive. The refractory chromite spinel fumes produced during oxygen blowing create an effective barrier to shield the roof from the bath. This neutral refractory spinel compound coats the working surfaces of the roof and apparently has no serious fluxing effect on the silica refractory.

Actually, life of silica roofs was doubled when oxygen blowing was substituted for the former solid-oxide oxidizing practice. Subsequent coatings of siliceous, aluminous or lime-rich fumes have very little fluxing effect on this base coat of refractory chromite. It was concluded that

(Continued on p. 202)

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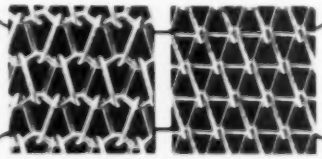

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Westward Ho!

BREAKING new ground is exciting—whether in Earth or Science. You start *digging* before you build, or plant, *anything*. The hole must precede the seed, as the seed the Harvest. In between, you don't stop "cultivating". Bumper crops come where nothing is left unturned. Tools with built-in brains are the guts of the job. The "guts" it takes to move earth is spelled "CAT".

We've jockeyed the best on legs, wheels, wings and keels, but man, oh man!—*you ain't rid nuthin* 'till you gun a "Cat". That most-damn functional tool makes mole hills out of mountains. "Nice big mountain we have, didn't we?" "To match it in spades" you need a digital computer!

Did you ever see a dream walking?—Well, we have! Our dream taking shape is called "Operation Horizons". We began by knocking-the-rough-spots-off a "Jr. Mountain" in southern California. The foreground tumbles precipitously to the sea, our 240° vista ranges down a meandering S.W. coastline, rising N. and N.E. up stair-stepped purple mountains. Snow-capped peaks, one hundred miles north, are visible at the whim of fog and "smog".*

In general, California has been too fully found. "Horizons" site remained virgin only because it was too hard-to-get-to. A 23.6% grade on the last 150 ft. was too steep for the "White Mice". The "Cat" fixed that in four weeks, with a half-mile of nominal-grade drives.

This philosophical indulgence in inspirational topography is a long-range program; *may prove fruitful*. General Alloys, firmly rooted in New England, dips a toe in the Pacific—just a "feeler". More about "Horizons" later.

This is written at the Western Metals Congress and Exposition at Los Angeles, a *successful* and *growing* A.S.M. activity. Some eastern companies are out here trying to "get a crack at their own tax money" pouring into Government subsidized industry. Hundreds have opened West Coast plants, and others will follow, as steadily increasing local industrial stature is everywhere evident. Contemporary Alloy Castings fall far short of GA standards. The background of experience is, quite naturally, lacking.

The Show was mobbed by bright folks waving like loose corn in a chute.

Many new and improved products were shown, a high percentage being of West Coast manufacture.

*Smoke & Fog—L. A.'s. Municipal Halitosis.

Hospitality was unexcelled. *Good Management* was evident throughout—A GOOD SHOW, AND A GRAND TIME!

"The Steel Game"

(with apologies to Bill Walkins of ESCO.)

Several visitors asked about casting in "shells"
Made from resin-bound sand not lacking in "smells"
Some noted how closely such "shells" are akin
To old-fashioned cores (with more "stickum" mixed in).
Much credit is due to ingenious mechanics
But two strikes remain on sands bound-with-organics.

We need *non-burning* bonds and that's for a *fact*
Sand bonds that, with metal, don't *wash* and *react*.

It does seem a shame that with science about,
We keep mixing *in* molds what we'd rather leave *out*.
Those defects, in castings, the buyers will pick 'em,
As long as sand's bonded with "mud" and with "stickum".

All stuff that makes steam, and oxides, and such,
In run o'mine castings "doesn't matter too much".
One reason, most castings a forging can't touch,
Is inclusions of oxide, wind, sand, and such.

"Shells" used for steel, may have "grief", maybe "joys",
Such as vintage Champagne for the "Boys".
There are many requirements "shell" molding can fill,
But for aircraft steel castings, we aren't waiting 'till.

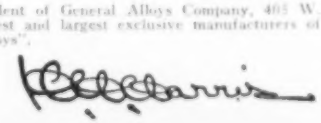
We think German process will lose decisions
In speed, cleaner castings, and higher precisions,
To new U. S. Process, by Navy inspired,
More closely approaching *all* goals desired.

The stuff you make molds of is *only one part*,
In "upgrading" process from Grandpappy's art.
Controlled melting, pouring and atmospheres,
Finish, patterns, inspection, are still in arrears.

— — —

Some folks are seeking to depart from crudities of old;
They think their arts should be *recast*, in a new and *better* mold.
Who feel, that *everyone* of us has *more* that he could give
To the arts and crafts and sciences by which we work and live.

an "editorial" by the President of General Alloys Company, 405 W. First St., Boston, Mass., "oldest and largest exclusive manufacturers of heat and corrosion resistant alloys".



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Performance of Refractories in Basic Arc Furnaces

(Continued from p. 200)

oxygen-blown stainless practice is not seriously corrosive toward the silica roof brick and for similar reasons toward the basic side-wall brick.

The relative corrosiveness of the five melting practices on silica roofs and metal encased magnesite-chrome side-walls were evaluated as follows, in decreasing order of severity: *(a)* Oxygen-blown alloy using carbide slag, *(b)* high-carbon alloy using carbide slag, *(c)* low carbon alloy using carbide slag, *(d)* single-slag practice, *(e)* oxygen-blown stainless.

The carbide slag practice, with the production of a reducing atmosphere, causes chemical reactions at the refractory working surface involving release of FeO which fluxes with the fumes produced during the carbide slag finishing period. Small pellets of reduced metal were usually found at the working surface of brick that had been subjected to the three practices employing carbide finishing slags, but were not found for the other two practices. Originally these pellets were believed to be "splash" from the bath, but from analyses of furnace atmospheres and fumes it was concluded that they were much more likely derived from reduced oxides that had coated the brick during the oxidizing period.

S. W. POOLE

Brittle Behavior in Pressure Vessel Steels*

SUDDEN FAILURE preceded by little plastic deformation and characterized by a high rate of crack propagation constitutes brittle behavior. It may be caused by rapid straining, multidirectional stresses or restraint imposed by notches of various origins, low operating temperature, or a combination of these factors. Brittle failures are generally ascribed to notch sensitivity of the steel, that is, its inability to deform plastically beneath a notch. However, brittle behavior may be encountered even in the absence of notches in internally loaded pressure vessels if the service imposes triaxial stresses.

No simple test reveals susceptibil-

(Continued on p. 204)

*Digest of "Transition From Ductile to Brittle Behavior in Pressure Vessel Steels", by T. N. Armstrong, N. A. Kahn and Helmut Thielsch, *Welding Research Supplement*, August 1952, p. 371s-380s.

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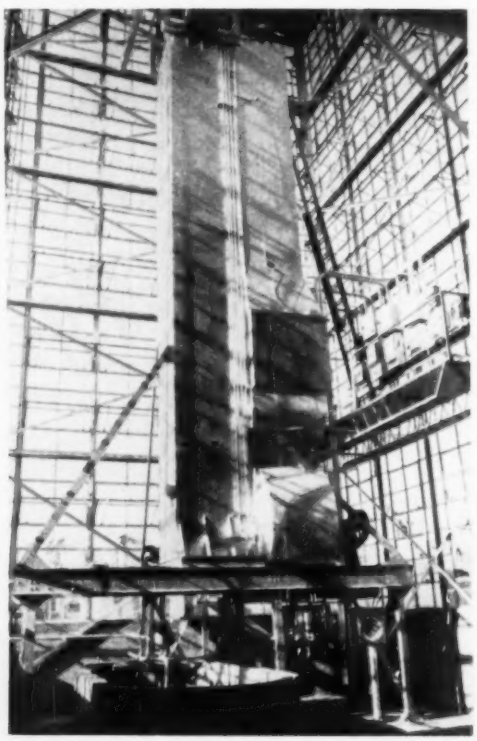

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Brittle Behavior in Pressure Vessel Steels

(Continued from p. 202)

ity to brittleness in a way that allows translation of the data directly into design for particular structures and service conditions. Nevertheless, several notched-bar tests provide data useful for material acceptance and correlation of metallurgical variables with notch sensitivity. Such methods include single-blow impact, slow bend, tensile and the Navy tear test, all performed with notched specimens. Large-scale tests simulating actual conditions, such as direct explosion tests and the "hatch corner" studies of welded ship construction, have proved useful in the study of design and welding practice.

The criterion of brittleness is usually the "transition temperature". With change in testing temperature, the transition is indicated by alteration in the appearance of the fracture, the ductility or the absorbed energy. Another criterion of acceptance is a specified energy value; for example, the 15 ft-lb. value with keyhole-notch specimens required by the 1950 Unfired Pressure Vessel Code, Section VIII, A.S.M.E. Boiler Construction Code for carbon and low-alloy steels for use below −20° F., and the A.S.T.M. Specification A300-51T for steel plates for service at low temperatures.

Transition phenomena are an inherent property of carbon and low-alloy steels, although the transition temperature varies not only with the steel but also with the criterion of transition employed. Mild structural steels may exhibit two transitions: The one at a relatively higher testing temperature is associated with the fracture transition; the "ductility" transition, at a lower testing temperature, with a drop in absorbed energy. The latter is particularly sensitive to notch geometry and conditions of prior strain. With sharper and deeper notches the ductility transition rises more rapidly than the fracture transition until the two merge. With certain types of specimens the fracture transitions observed with two lots of steel may be nearly alike while the ductility transitions are more separated.

METALLURGICAL FACTORS

Alloying additions, with the exceptions of nickel and sometimes manganese, usually raise the transition temperature, as do metalloids

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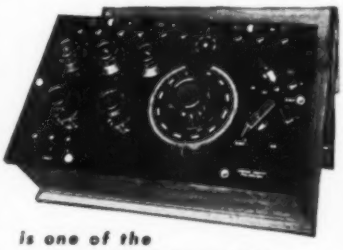

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in amounts larger than customarily tolerated or when intentionally added. Normal chemistry variations in the ingot cause some spread in transition values. Also, cross-rolled plate may differ from direct rolled product.

Fine grain structure generally lowers the transition temperature. Fine grain may be obtained by an appropriate aluminum addition, followed by a low finishing temperature or by heat treatment.

Cold deformation tends to raise the transition temperature. The ductility transition is affected first, and after merging of the ductility and fracture transitions, both are raised.

Structural steel is generally used in the as-rolled condition, thus the finishing temperature of the hot-rolling operation controls the structural state of the plate. The higher finishing temperatures and slower cooling rates usually associated with the finishing to thicker sections generally raise the transition temperature.

Transition temperatures usually fall in the order of lowest after liquid quenching, intermediate after normalizing and highest in the as-rolled state. Stress relieving between 900 and 1100° F. often decreases the probability of brittle failure, but the intervals around 1400 and below 900° F. are to be avoided because they may raise the transition temperature. In steels which are susceptible to aging, the onset of aging raises their transition temperature.

MECHANICAL FACTORS

Satisfactory design of pressure vessels should not be based on conventional tensile data alone, nor does increase in section size always provide a factor of safety against brittle failure. Notches should be avoided by using generous radii and by limiting the use of materials having surface defects. Undesirable design features, when necessary, may be offset by use of low design stresses and steel of low sensitivity to notches, and elimination of shock and low temperatures during service.

Welding workmanship is highly important and the judgment of the operator may be supplemented by radiographic, magnetic or other inspection as a means of control of both structure and soundness of the weld deposit. The heat-affected zone should be as narrow as possible.

Choice of electrodes and welding procedures are critical factors. Investigations have shown that electrodes of the E6010 type produce

(Continued on p. 206)

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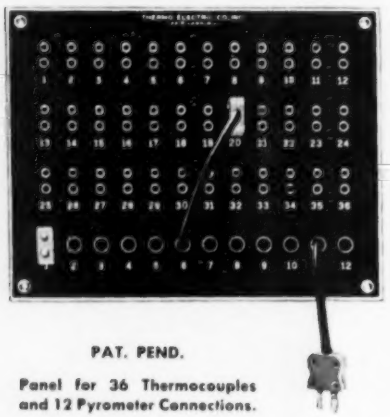

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Brittle Behavior in Pressure Vessel Steels

(Continued from p. 205)

microcracks as the weld cools below 500° F., whereas the E7015 and E7016 circumvent the difficulty. Preheat and interpass temperatures and the degree of restraint during cooling influence susceptibility to brittleness. Also the weld deposit becomes less ductile as the temperature is decreased – this may amount to as much as 15 to 20% (using impact tests for evaluation) when the welding done at −50° F. is compared to that at 75° F.

All-welded structures contain residual stresses. When of a serious nature they may require a stress-relieving treatment.

The authors conclude with a plea for more study of both metallurgical and mechanical features to bridge the gap between the information obtained with laboratory tests and the service behavior of welded pressure vessels.

M. BAEYERTZ

Inert-Gas-Arc Welding of Copper*

IN ORDER TO "fusion" weld any metal, the rate of heat input to the zone of fusion must be greater than the rate of heat conduction away from that zone. Thus, because of its high thermal conductivity, copper is more difficult to weld than most other metals. Preheating of the work is helpful, however.

Although the electric arc is the most intense source of heating available for welding, neither metal-arc nor carbon-arc welding has been too successful for welding copper. However, inert-gas metal-arc welding, using nonconsuming electrodes – usually pure tungsten – appears to be satisfactory and has the following advantages over other processes:

1. Flux is not necessary.
2. Concentrated heating gives higher welding speeds.
3. Smaller heat-affected zone.
4. Less distortion.
5. The arc atmosphere is inactive.
6. Better weld properties.

For welding copper with this process, direct current with straight polarity (electrode negative) is recom-

*Digest of "Argon-Arc Welding of Copper", by J. H. Cole, *Welding Research*, Vol. 6, August 1952, p. 83r-86r.

mended. For some of the copper alloys, such as aluminum bronze, alternating current is recommended; with this a high-voltage high-frequency current superimposed on the welding current is essential for ease of starting and maintaining arc stability. The superimposed high-frequency current is desirable with direct-current welding because it facilitates starting the arc without touching the electrode to the workpiece, thus minimizing possible contamination of the weld as well as of the electrode.

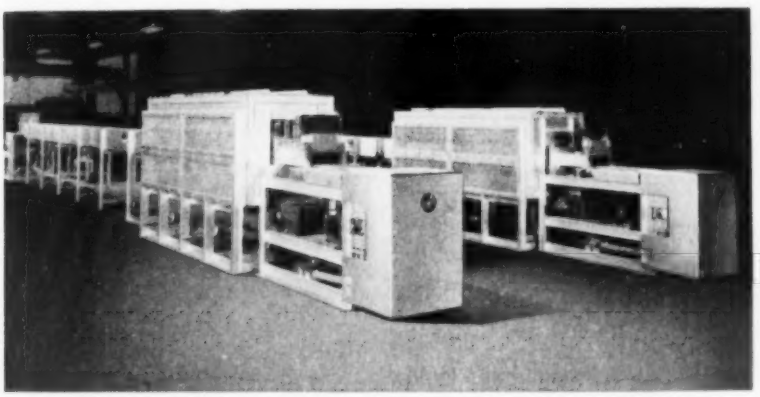
At the present time the inert-gas metal-arc process, with consumable copper electrode, is being developed and this process appears to be applicable to the welding of copper and its alloys.

Both argon and helium are used satisfactorily as shielding gases. Since the arc voltage in helium is higher than in argon, the arc energy input to the work, for the same current, is greater with helium. For this reason, with the same current setting of the welding generator, the current in the argon arc is greater. Thus, for the same welding speed, a higher current setting is required when using argon. Nitrogen, inert to copper, has been tried as a shielding gas but the resulting welds were of low strength and had considerable tungsten contamination.

For butt welds in sheet ⅛ in. thick or less, a closed square edge joint is satisfactory with the addition of filler metal. For material over ⅛ in. thick, a closed 90° single-V joint is satisfactory, except that for thicknesses of ½ in. or greater a single-U or double-U joint groove reduces the amount of filler metal required. A copper backing-bar is used except for welding thin sheet, and this is either clamped or tack-welded to the back of the plate and the root layer is fused into the backing-bar.

Welding without a backing-bar can be accomplished by using a ⅛-in. root face in the joint groove and not penetrating through with the root layer. In this technique the joint is "back chipped" to sound weld metal and the joint completed by "back welding". Preheating up to about 1000° F. is desirable for sections ¼ in. thick and more to obtain sound-

(Continued on p. 208)



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Inert-Gas-Arc Welding of Copper

(Continued from p. 207)

ness of weld and a satisfactory speed of welding. Since there is no beneficial annealing effect of laying one layer of weld metal on top of another, it is more economical to weld with a minimum number of passes.

During the welding of tough pitch copper (0.04% O_2) any oxide present in the base metal will form an intergranular eutectic in the weld metal which produces low ductility. Any air inspirated by the shielding gas jet will increase this eutectic formation. Moisture in the shielding gas or inspirated air is a source of hydrogen which, by reaction with the oxide in the weld metal, produces porosity in the weld. In order to obtain sound welds the parent plate should be oxygen-free and the filler metal should contain a small amount of a suitable deoxidizer.

Welds in tough pitch copper usually have variable physical properties, particularly bend ductility. Sound welds in cold rolled plate usually have the tensile strength of annealed plate and failure occurs in the heat-affected zone.

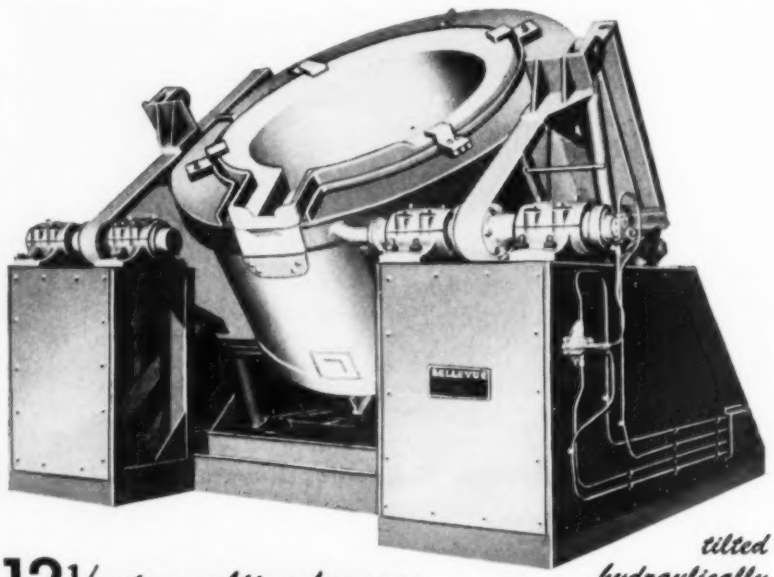
The author concludes that deoxidized copper sheet or plate can be welded by the inert-gas tungsten metal arc, with the welds having the strength and ductility of fully annealed parent metal. The oxygen-containing copper sheet or plate can be welded, but the physical properties of the joint are variable.

W. L. WARNER

Methods for Aluminum Sheathing of Cables*

AS FLAT-ROLLED aluminum becomes available in larger quantities, its possibilities as a material for sheathing cables, both large and small, excite heightened interest. Applications have the benefit of proved field service in power transmission and communications. However, the choice of aluminum as an alternate for lead is governed by the economics of supply.

*Digest of "Aluminum as a Cable Sheathing Material", by D. McAllister, *The Engineer*, Vol. 194, Dec. 19, 1952, p. 819-823.



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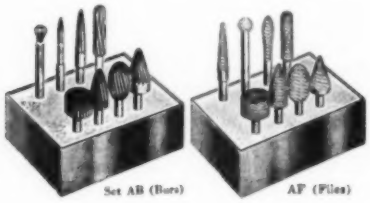

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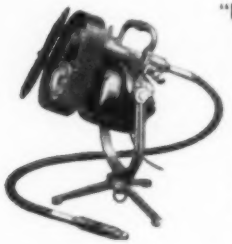

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Weight savings in power cables are noteworthy, ranging from 60% in small sizes to 30% for larger diameters, with an average of 35% for unarmored and 25% for armored cables. Furthermore, aluminum provides mechanical strength and resistance to scoring not found with lead. On the other hand, flexibility and ease of cutting and plumbing are points in favor of the softer metal.

First large-scale use of aluminum cable sheaths was in Germany over ten years ago. Two methods of application were devised. One involved folding a strip of aluminum around the cable and resistance welding an upset longitudinal flange; the other, direct extrusion of the sheath around the cable. The first met with little success, while the extrusion method apparently had to mark time awaiting the development of suitable presses.

British cable makers took up the work after the war and centered their attention on two sheathing methods – welding the folded strip and "dieing down" an aluminum tube into which the cable had first been drawn. The second proved the simplest and most satisfactory, except that a considerable length of plant space is needed. For example, in modern cable practice, lengths of 440 yd. are common, and to accommodate them an equivalent length of sheath tubing must be laid out in a fairly straight line.

The cable is first drawn into the tubing and the assembly then is pulled back through a "sinking" die which reduces the diameter, but not the wall thickness, to produce a tight fit. The amount by which tubing can be conveniently reduced in diameter by dieing down is limited to between 40 and 45% in small sizes.

Hardening occurs in the reduction, so the original tubing must be as soft as possible, preferably in the as-extruded condition. With very small tubing it is usually the practice of suppliers to extrude a larger size, then draw down, degrease and anneal.

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(Continued on p. 210)

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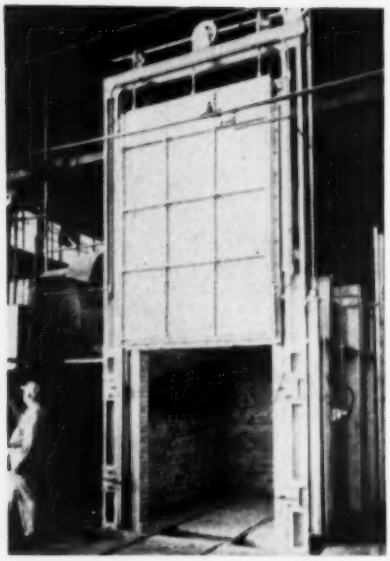

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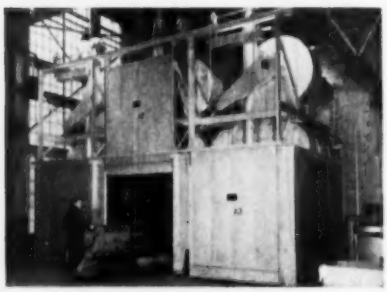

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Methods for Aluminum Sheathing of Cables

(Continued from p. 209)

layer on the surface of the tube, thus avoiding the necessity for degreasing which would be required if oils or greases were used.

Cable sheaths of lead are applied universally by the extrusion method. Presses for extruding aluminum sheaths would require three times the power and would involve special design for introducing the cable through the ram and solid billet of metal ahead of the extrusion die. Higher temperatures of aluminum extrusion also complicate the technique, since they could result in possible damage to cable insulation.

A. H. ALLEN

Determining Texture From X-Ray Diffraction Photographs*

A METHOD IS DESCRIBED whereby the orientation texture of cold rolled sheet can be determined directly from the X-ray diffraction patterns. The information is also sufficient for the complete pole figure determination. While the procedure is worked out for cold rolled steel, the method can be applied to any rolled metal. The method is concerned mainly with the deviations from the ideal orientation, which is now generally known for all of the important metals and alloys.

The rolling texture of a metal is based upon a single orientation and the deviation or scatter from it. In some instances the rolling texture may have several orientations. The problem is to determine the scatter from it, by a method which requires the minimum of X-ray diffraction data. Only two X-ray diffraction patterns are required to find the deviations from the ideal texture. These are obtained by the procedure outlined as follows:

The X-ray beam is reflected from the surface of the specimen. The angle chosen corresponds to the Bragg angle of an important crystal plane of a low index. When MoK radiation is used, the beam is reflected at 10° from the surface. The

*Digest of "The Determination of the Texture of Rolled Sheet From X-Ray Diffraction Photographs", by A. E. De Barr and B. Roberts, *Journal* of the Iron and Steel Institute, Vol. 164, March 1950, p. 285-287.

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(110) planes, which lie parallel to the rolling or transverse rolling direction, will be in the proper position to reflect the X-ray beam. With this data it is possible to determine directly how the (110) planes are oriented with respect to the rolling and transverse rolling directions.

Two specimens are required so that the first X-ray pattern, called the T pattern, is made by reflecting the X-ray beam at an angle of 10° to the surface, and transverse to the rolling direction. The second, or P pattern, is made by reflecting the X-ray beam at an angle of 10° to the surface and along the rolling direction.

COMMENTS BY THE REVIEWER

A comparison of the P and T patterns shows that the orientation texture is most intensely and sharply defined in the T direction. The P patterns usually indicate that the crystallites are more or less oriented at random in this direction. The diffraction rings also show that the crystallites of the plastically deformed metal are small, about 10^{-5} cm.

This method of analysis was used by the reviewer to prove that the rolling texture developed in strips of α iron is temperature-dependent. ("The Effect of Temperature on the Rolling Texture of Plastically Deformed Low Carbon Steel Strip", *Transactions* ASM, Vol. 45, 1953, p. 333. The effect of temperature is most sensitively shown by making X-ray diffraction patterns in the T direction. The effect of variables which enter into rolling, such as roll diameter, rolling speed, tension, temperature, direction of pass, roll friction (lubrication), reduction per pass, and total reduction, can be followed with this system of analysis.

N. P. Goss

Mechanism of Metallic Bonding*

AMONG the fundamental considerations of surface alloying in brazing and bonding of metals is that the mechanism of metallic bonding is related to attractive forces between atoms and by the movement

(Continued on p. 212)

*Digest of "Surface Alloying in Brazing and Related Techniques", by Robert Humphrey and Rene D. Wasserman, *Welding Journal*, Vol. 31, December 1952, p. 1135-1140.

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Mechanism of Metallic Bonding

(Continued from p. 211)

of atoms within a solution. The latter action is a function of pressure, temperature and concentration, and usually moves from regions of high concentration to low concentration.

Brazing can be conducted in the open or in a controlled atmosphere, but in both methods the filler metal must have certain characteristics. "Wetting", or the ability to spread, is one of these. In turn, the alloying capacity of the metals involved appears to limit their wetting qualities. The capability of the metals to alloy can be determined from the behavior of the phases in the constitutional system for these metals.

Long periods at high temperatures should be avoided because they may lead to distortion, excessive grain growth, porosity and burning. Eutectic composites minimize these dangers. However, it is not always practicable to use pure eutectic compositions, since excessive cooling strains may result which will cause cracking. Therefore, alloy compositions close to the eutectic composition are used to give improved brazing properties.

To effect metallic bonding as in brazing, the preparation of mating surfaces is of the highest importance, and the three principal methods of cleaning are: *(a)* Fluxing with salts to dissolve and absorb oxide films, *(b)* reducing oxide films with suitable gases, and *(c)* immersing in molten baths which combine both oxide absorption and reduction.

Certain activating compounds often are added to brazing fluxes to facilitate complete wetting of base metal surfaces and the brazing alloy as well. A well-balanced composition usually contains fluorides, chlorides, borates and small quantities of the aforementioned activators. The flux should have the following properties: *(a)* Produce no excessive runoff, *(b)* melt below the melting point of the brazing alloy, *(c)* reduce or dissolve the oxide film, *(d)* wet the base metal and the brazing alloy, *(e)* protect the base metal from oxidation during heating, *(f)* activate the surface for brazing, *(g)* be displaced by the liquid brazing alloy.

The flux may contain metal ions which can be reduced and deposited on the base metal at temperatures far below the melting points of the brazing materials. This is true particularly when the deposited ions are low-melting elements, easily alloyable to the base metal. In this case, brazing takes place readily because the diffusion occurs to atomically clean surfaces having high surface mobility, and because the two surfaces of the base metals alloy with the liquid brazing material by means of a low melting interface.

Better knowledge of the mechanics of metal bonding and surface preparation has been put to work in the development of new and superior brazing alloys and fluxes, now available commercially. Their incidence has been speeded by a more thorough metallurgical understanding of equilibrium diagrams of the binary alloy systems, covering metals commonly used in brazing and related techniques.

A. H. ALLEN

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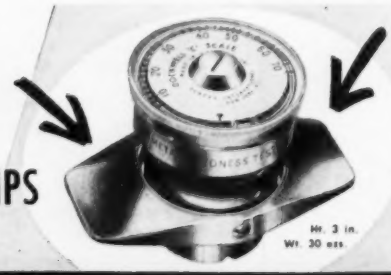

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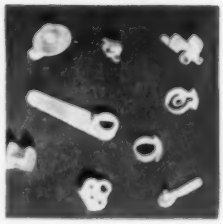

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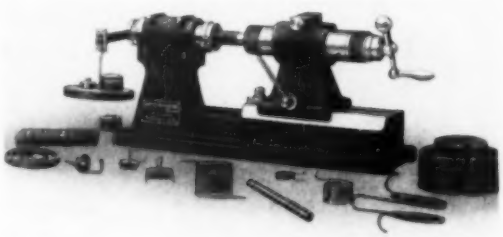

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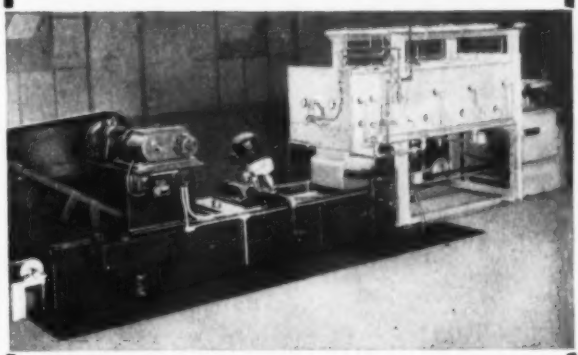

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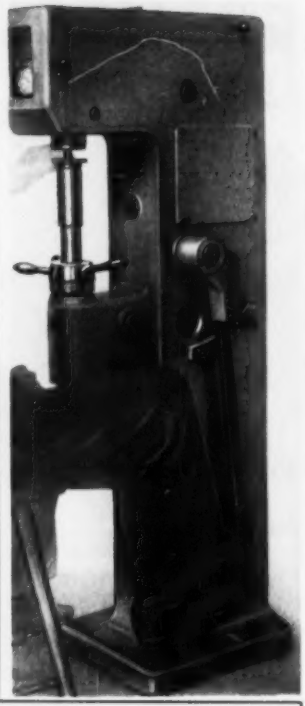

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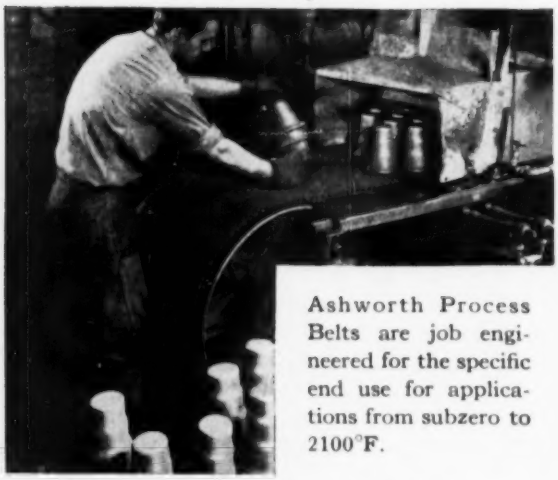

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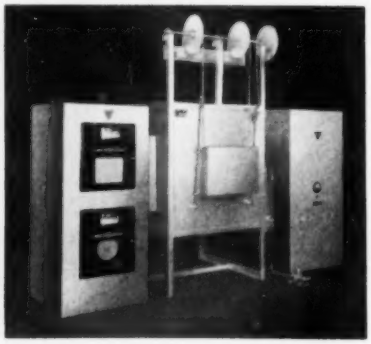

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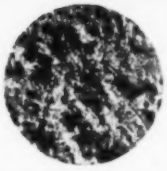	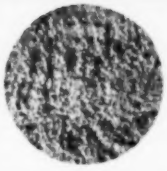

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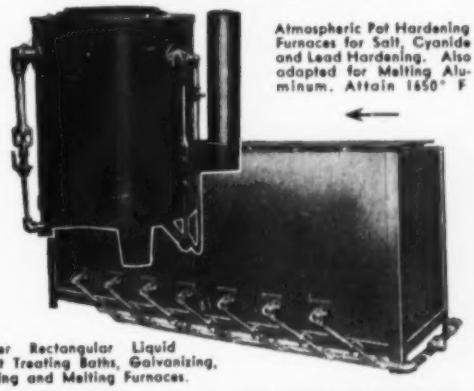

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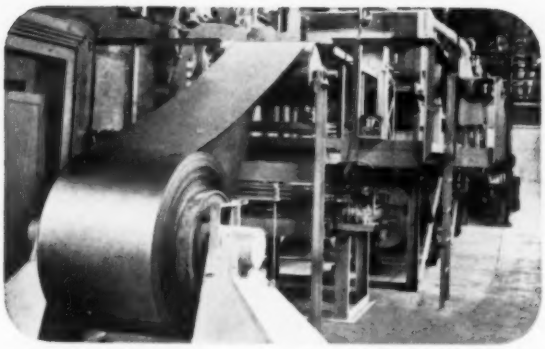

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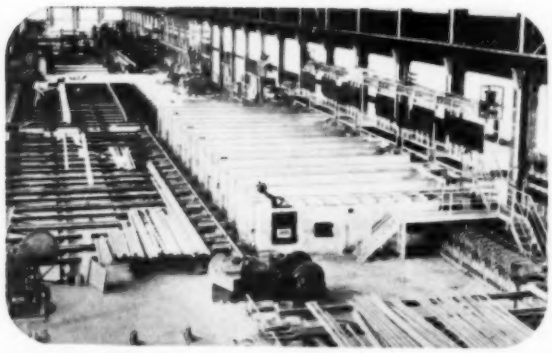

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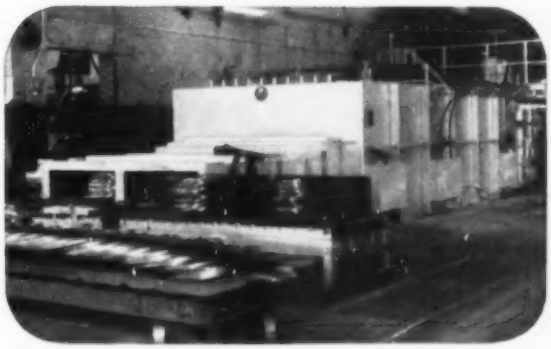

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